DEVELOPING A NEW POLICY FRAMEWORK

FOR

THE USE OF COMBINED HEAT & POWER TECHNOLOGY

IN

SMALL & MEDIUM ENTERPRISES

A Thesis submitted to Middlesex University in partial fulfilment of the requirements for the degree of Doctor of Philosophy

By

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STATEMENT OF ORIGINALITY

Except where other wise stated, this thesis is entirely the result of my own research

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ABSTRACT

The aim of this research is to develop a new policy framework for the use of Combined Heat & Power systems[1] (CHP) in Small and Medium Sized Enterprises[2] (SMEs). This entailed an assessment of the extent to which the current national policy framework for the use of CHP is effective and from contemporary data obtained from CHP operators, policy makers, designers and regulators, subsequently to develop a new policy framework.

The design of the research process combines the strengths of engineering, economic and social policy academic disciplines for an examination of the potential for the use of CHP in SMEs. The research methodology dictated the use of qualitative and quantitative methods for data collection. The analyses of the data collected formed the basis for proposing a new Governance policy framework designed to encourage the use of CHP in the SMEs. The new Governance framework is proposed as an amalgamation of Support Systems set on the macro and micro levels of SME governance. A Governance Support System (GSS) offers SMEs an integrated structure for regional sustainable development, including flexible decision support base. The Business Decision Support System (BDSS) is designed as a simple tool for use by SME managers' considering CHP as part of any proposal involving capacity constraints for heat or electricity in the business. The thesis concludes that proactive adoption of the new Governance framework would allow for easier access of SMEs to CHP systems as well as assisting the Government in meeting its climate change objectives.

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[1] A CHP system is one that simultaneously produces heat and electricity in a single process.

[2] Enterprises that employ less than 250 staff, with an annual turnover no more than 40 million Euros and is less than 25% owned by a large enterprise.

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I thank my wife, family, colleagues and friends who have spent many hours in the editing of the thesis, sometimes with little enthusiasm for the depth and the topic of the research. I am grateful for the time that they have spent on this tedious and sometimes painful exercise and trust that their confidence in me has not been misplaced. The completion and indeed the commencement of this sojourn of research would not have been possible without an able wife and a supportive family. I will always remain indebted for the sacrifice that they have made over the past five years in allowing me the time and space to complete the study. Finally I would like to dedicate this thesis to my parents- Wesley and Patricia Webber, both sadly deceased-whose infant nurture and sacrifice was the framework for the achievement of a doctorate degree.

List of Abbreviations

ACE	Association for the Conservation of Energy
ACBE	Advisory Committee for Business and the Environment
AEP	Association of Electricity Producers
BATNEEC	Best Available Technology not Entailing Excessive Costs
BDSS	Business Decision Support System
BETTA	British Electricity Trading and Transmission Arrangements
BRE	Building Research Establishment
BRESEC	Building Research Establishment Sustainable Energy Centre
CBI	Confederation of British Industries
CCL	Climate Change Levy
CE	Cambridge Econometrics
CEM	Contract Energy Management
CESMB	Centre for Environmental and Safety Management for Business
CDM	Clean Development Mechanism
CHP	Combined Heat & Power
CHPA	Combined Heat & Power Association
CHPQA	Combined Heat & Power Quality Assurance
CIBSE	Chartered Institute of Building Service Engineers
COGEN	European Association of Co-generators
CRI	Community Renewables Initiative
CT	Carbon Trust
DEFRA	Department of the Environment, Food & Rural affairs
DETR	Department of Transport and the Regions
DTI	Department of Trade And Industry
DUKES	Digest of United Kingdom Energy Statistics
DSS	Decision Support Systems
EC	European Commission
ECA	Enhanced Capital Allowances
ECOTEC	'ECOTEC' Research Laboratory Ltd
EEAC	Energy Efficiency Advice Centre
EEBPp	Energy Efficiency Best Practice Programme
EGWG	Embedded Generation Working Group
ENDS	Environmental Data Services Ltd
EPM 35	Energy Performance Model, Number 35
ENDS	Environmental Data Support Services
ESCO	Energy Service Company
EST	Energy Saving Trust
ETSU	Energy Technology And Support Unit
EU	European Union
EUETS	European Union Emissions Trading Scheme
GLA	Greater London Authority
GWhr	Giga Watt Hours
GWe	Giga Watt Electrical Output

HCV	Higher Calorific Value
HECA	Homes Energy Conservation Act
IEA	International Energy Agency
IPCC	Inter- Governmental Panel for Climate Change
IPPC	Integrated Pollution Prevention and Control
IRR	Internal Rate of Return
KWhr	Kilowatt Hours
IPSEP	International Project for Sustainable Energy Paths
KWe	Kilowatt Electrical Output
KWth	Kilowatt Thermal Heat Output
LDA	London Development Agency
LGMB	Local Government Management Board
MEP	Member of the European Parliament
MTOE	Million Tonnes of Oil Equivalent
MWhr	Megawatt Hours
MWe	Megawatt Electrical Output
MWth	Megawatt Thermal Heat Output
MtC	Million Tonnes of Carbon
NETA	New Electricity Trading Arrangements
NI	National Insurance
NUD*IST	Qualitative Analysis Software Trademark
NPV	Net Present Value
OECD	Organisation for Economic Corporation and Development
OFFER	Office for Energy Regulation
Ofgem	Office of the Gas And Electricity Markets
PRASEG	Parliamentary Renewable and Sustainability Energy Group
PIU	Policy and Innovation Unit
PJ	Peta Joules
PPP	Producer pays for Packaging Regulations
PV	Photo voltaic solar cells
QPC	Qualifying Power Capacity
QPO	Qualifying Power Output
REC	Regional Electricity Companies
REST	Renewable Energy Source Technologies
RPI	Retail Purchase Index
SAVE	Specific Action for the Valorisation of Energy
SDC	Sustainable Development Commission
SEC	Sustainable Energy Centre
SME	Small & Medium Enterprises
SMEEEAC	Small & Medium Enterprises Energy Efficiency Advice Centre
SPRN	Sustainable Policy Research Network
SPN	Sustainable Policy Network
TJ	Tera Joules
TM	Technical Memorandum
UNCED	United Nations Commission for Environmental Development
UNFCC	United Nations Framework Convention on Climate Change

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SAVING THE PLANET IS A BUSINESS OPPORTUNITY NOT TO BE MISSED

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Chapter 1

Our Changing World-Background to the Research

1.1 Introduction- The environmental effects of climate change

Changing environmental patterns across the world have elevated discussions about climate change[1] and global warming[2] to the forefront of political and business discussions over the past 15 years. Floods, droughts, rising sea levels and increasing surface air temperatures have all been markers of the effects of global warming. Of the sixteen warmest years in Central England since 1659, no fewer than eight have occurred since 1989 (Hadley Centre, 2002). The warming of the UK climate also has consequences for daily temperature extremes. An increase in the frequency of "very hot" days in central England has occurred since the 1960s, with a number of particularly extreme summers being experienced – 1976, 1983, 1990 and 1995. Extremes of temperature – whether intense cold in winter or intense heat in summer - often have a great social impact (Boot, P.1998).

The year 2000 also recorded the wettest autumn in England and Wales when very nearly twice the seasonal average of 257 mm of rain was recorded. This indicates that large scale changes in circulation – such as the North Atlantic Oscillation – that regulate precipitation variability are generally effective across the whole UK (IPCC, 2002).

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[1] Global warming is the increase in the earth's surface temperature as a result of Climate Change

A comparison of the observed patterns of warming, with model simulated patterns resulting from natural and man made factors, indicates that over the last 50 years most of the observed change can be explained by human activities, mainly the production of Carbon Dioxide (CO_2) from burning fossil fuels (Hadley Centre, 2000). The possible effects of global warming are:

- Decreased crop yields
- Increased damage to buildings due to ground shrinkage
- Increased risk of forest fire
- Increased coastal erosion & damage to coastal ecosystems

In the IPCC 3rd assessment report, the global average temperature between 1990 and 2100 is projected to rise by 1.4^{0}C to 5.8^{0}C and the mean sea level is projected to rise by 9cm to 88cm (IPCC, 2001). This increase in surface temperature has been attributed to the effects of the build up of greenhouse gases in the atmosphere (Table 1.1). As the largest greenhouse gas, the CO_2 emissions profile has been extensively studied and led to the projection of a 75% increase in CO_2 emissions between 1995 and 2020 unless a concerted action is taken to reduce it (IEA, 1998).

Table 1.1 The Kyoto Basket of Six Greenhouse Gases (1998)

Gas	**UK Emissions 10^3 Tonnes (1998)**
Carbon Dioxide	572,902
Sulphur Hexa-fluoride	0.054
Methane	2637
Nitrous Oxide	181
Hydro-fluorocarbons	3656
Per-fluorocarbons	0.094

Source: www.aeat.co.uk/netcen/airqual/naei/annreport/annrep98/chap2

1.2 The UK Government's response to climate change

Since the UN World Earth Summit on sustainable development[3], in Rio de Janeiro, Brazil, 1992, the debate on human modifications to the greenhouse effect[4] (mainly connected with CO_2 emissions) became intensified at national and international levels. Sustainable development principles also point out that external, social and environmental consequences arising from production systems must be taken into consideration in decision making at all levels of business (UNCED, 1992). At this summit, the UK Government, along with 153 countries, signed a declaration to limit the amount of greenhouse gas emissions on a global scale (UN, 1993). At the subsequent Conference of the Parties to the United Nations Framework Convention on Climate Change, Kyoto, Japan, 1997, the UK signed the Kyoto Protocol, in which it agreed to a 12.5% reduction in its 1990 CO_2 emissions by 2010. In addition, the UK voluntarily extended this target to a domestic target of a 20% reduction (DEFRA, 1997a).

The practical application of the declaration was further confirmed at a further World Summit on Sustainable Development in Johannesburg, South Africa, in 2002. The declaration at this summit made it clear that delivering sustainable development is not a task for Governments alone, "the Business Community, the Voluntary Sector, Local Authorities, Professional bodies and individual citizens all have to play a part" (UNCED, 2002).

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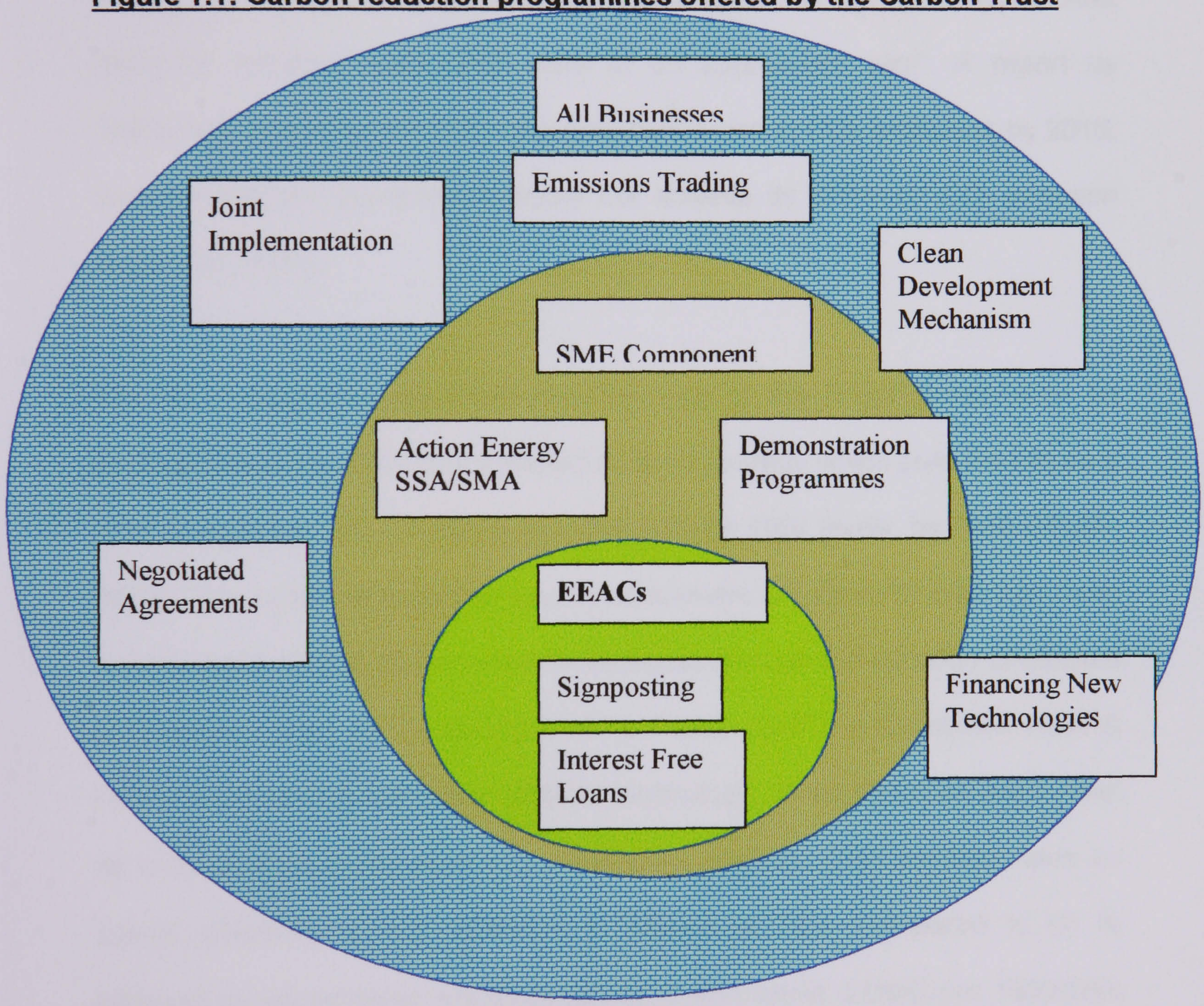
[3] Development that meet the needs of the present without compromising the ability of future generations to meet their own needs (WCED, 1987)

[4] The greenhouse effect is a phenomenon of trapping sunlight within the atmosphere thereby creating a warming 'greenhouse' effect on the earth (IPPC, 1996)

The UK Government's concern about long term energy supplies, developed from the European Commission (EC) statement, that if no abatement measures on energy use are taken in the next 20-30 years, 70% of its energy requirements, would have to be imported (EC, 2001). Concerns about the effects of global warming subsequently prompted changes to policies for use of fossil fuels. These policy changes included new fiscal measures and setting up the Carbon Trust within a governance framework shown in Figure 1.1.

Figure 1.1: Carbon reduction programmes offered by the Carbon Trust



Source: Energy Saving Trust, 2001

The Carbon Trust is set up to manage the UK's climate change programme with respect to Businesses and is recognition of the importance of the business use of energy (DTI, 2003). The Energy White Paper also continued to identify CHP as having a significant potential to contribute to the reduction of CO_2 emissions in the UK, by confirming the target of 10000 MWe (10GWe) of available capacity for CHP by 2010, already set in 1998 (DTI, 2003). The Performance and Innovation Unit (PIU) suggested that "*CHP provides the most efficient way of using fossil fuels and biomass, so that by 2050, all low temperature heat could be provided from CHP units of an appropriate size*". A report by Cambridge Econometrics (CE) also predicted a rise in CO_2 emissions by 2010, implying that the Government would not achieve its domestic CO_2 emission target (CE, 2002).

The UK Government also accepted the view of the Royal Commission on Environmental Pollution, that it should adopt a strategy which puts the UK on a path to reducing CO_2 emissions by some 60% on 1997 levels, by 2050 (RCEP, 2000). The earlier strategy pursued by successive UK Governments had been to encourage energy conservation, in particular through the adoption of efficient technologies such as Combined Heat & Power (CHP). A Combined Heat & Power systems is a highly fuel efficient technology, which produces waste heat as a by product of the electricity generation process. CHP systems have an overall efficiency of fuel utilisation in excess of 75%, compared to 40 % achieved by conventional electricity plants. It also saves 0.8MtC per 1000MWe compared to electricity only generation plants (DTI, 2003).

In industrial and commercial businesses, energy efficiency is often the result of investments in modern equipment that consume energy and allows for a focus on business decision-making. The Government's climate change strategy therefore accepts that energy consumption is a pre-requisite for sound industrial and economic performance (DEFRA, 1999). Of note is that a key issue affecting the use of energy efficient technologies in the business sector is that of low utility costs. This low utility cost became significant after the liberalisation of the energy markets in 1989, and became more marked within the electricity markets in 2001, after the adoption of the New Electricity Trading Arrangements (NETA) (DTI, 2001).This is a consequence of electricity generators using coal to fill the gap in electricity production, resulting from closure of the UK's ageing nuclear energy plants[5]. The previous Conservative Government (1992-1997) had set a target to increase CHP capacity to 5000 MWe, by the end of the year 2000. At the end of the year 2000, installed CHP capacity was 4730 MWe (DTI, 2001b).

At the end of 2001, CHP capacity was 4753MWe, an increase of just over 0.8% in installed capacity and below the targeted 5500 MWe. At the end of 2002 there were 1539 CHP schemes with an aggregate capacity of 4742MWe, which was 11Mwe lower than 2001 (DTI, 2003a). Figure 1.2 shows the capacity levels of CHP installations from 1977 to 2002, the red line, a projection of what is likely to be installed by 2010, indicates a shortfall of about 3000 MWe.

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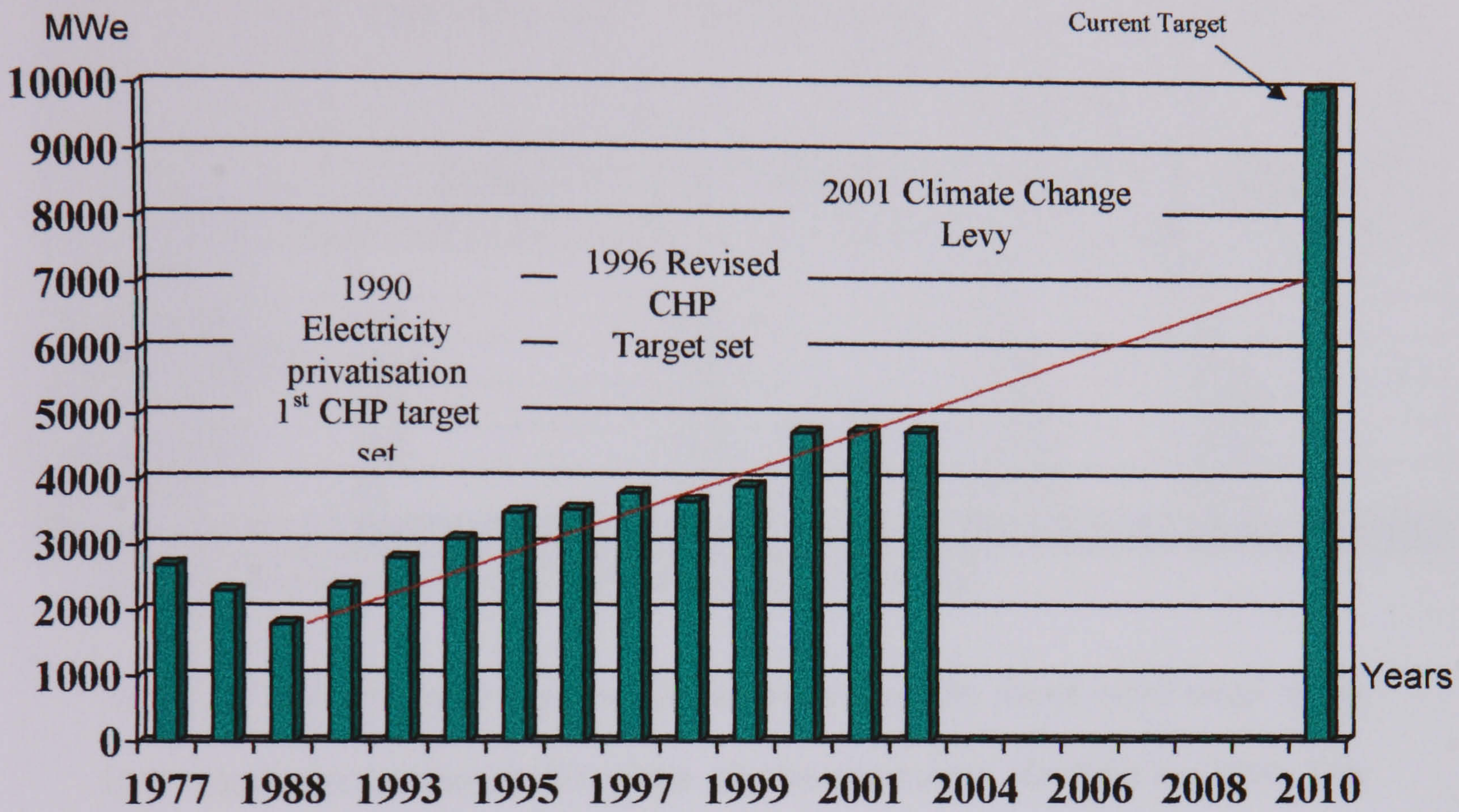
[5] All but one of the UK's nuclear power stations are due to be decommissioned by 2025 (Praseg, 2002)

Figure 1.2: Actual and projected installations of CHP capacity in the UK

Source: Digest of United Kingdom Energy Statistics (DUKES) DTI, 2003a



An earlier study conducted by the Future Energy Solutions[6] (FES) had provided estimates of the market potential for various sizes of CHP plant up to the year 2010 (FES, 1997a). The FES study had concluded that a capacity target of 8MWe was more readily achievable than the Government target of 10MWe. Table 1.2 compares the Government's expected number & capacity of CHP installed by 2010, based on a target of 10GWe with that suggested by FES, based on an 8GWe target. FES had noted that the Government's target represented an over reliance on estimates of economic growth by Cambridge Econometrics.

[6] It was previously named Energy Technology Support Unit (ETSU) in 1997, owned by the Government.

Table 1.2: Predicted Number/Capacity of CHP schemes in the UK, by 2010

	FES Target No. of CHP schemes	Government Target No. of CHP schemes	FES Target Capacity	Government Target Capacity
	8GWe	**10GWe**	8GWe	**10GWe**
< 5 KWe	0	0	0	0
5-500KWe	532	665	18	21
500KWe-5MWe	1534	1919	283	354
5-50MWe	272	340	1313	1642
10-50MWe	100	125	2164	2705
> 50MWe	40	50	4222	5278
Total	**2478**	**3098**	**8000**	**10000**

Source: Assessment of CHP Potential, (FES, 1997a)

Table 1.2 also indicates that the Government expects about 1919 small scale CHP installations between 500 KWe -5MWe producing 354GWe by 2010. The level achieved in 2002 (Table 1.3) was much less than that predicted, particularly in the small scale CHP sector (500KWe-5MWe), which is the size band generally used by commercial and small business organisations (FES, 1997a). At the end of 2002, only 175 such schemes were operational with a capacity of 372MWe as shown in Table 1.3. This comparative analysis suggests that there is considerable scope within the UK to achieve a much higher level of use of CHP in the SME business sector, than is currently being realised.

The gap between the actual numbers of installations as indicated by Table 1.3, compared to the projection in Table 1.2, is an indication of the policy gap that exists for CHP in the UK. It also shows the limitations of the climate change package of measures (DEFRA, 2000c) and the need for implementing a new national CHP strategy.

Table 1.3: Breakdown of CHP schemes in the UK by size (end 2002)

	Total Schemes	% of No.	QPC (MWe)	% QPC[7]	QPO (GWh)	% QPO[8]	TPC[9] (MWe)	TPO[10] (GWh)
Micro CHP < 5 kWe	0	0	0	0	0	0	0	0
Mini CHP 5 -500 KWe	1237	80	154	3	728	3	154	729
Small Scale 500KWe - 5MWe	175	11	372	8	1771	7	379	1871
Medium Scale 5-50MWe	98	6	1237	26	6468	27	1358	6714
Large Scale 10-50MWe	29	2	2980	63	15269	63	8679	36072
Total	**1539**	**100**	**4742**	**100**	**24236**	**100**	**10570**	**45385**

Source: DTI, Digest of UK Energy Statistics, 2003a

In the case of CHP, the need for a policy framework that addresses in an incremental way, the hierarchy of energy use becomes more relevant to SMEs, than the use of fiscal instruments. The energy hierarchy (Use Energy Efficiently; Use Renewable Energy; Supply Energy Efficiently) was noted in the Mayor of London's draft energy strategy as being a prerequisite for the effective implementation of any strategic energy framework (GLA, 2003).

[7] QPC- Qualifying Power Capacity- registered power generation capacity (MWe) qualifying as good quality CHP capacity
[8] QPO-Qualifying Power Output – registered annual power generation (MWh) qualifying as good quality CHP capacity
[9] TPC- Total power Capacity-registered maximum power generation capacity (MWe) of a CHP scheme
[10] TPO- Total Power Output-registered annual power output capacity (MWe) of a CHP scheme

Whilst the Government has developed strong policy initiatives for encouraging energy efficiency in the domestic sector such as the Homes Energy Conservation Act (DEFRA, 1995) and negotiated energy agreements for the large industry sector (DTI, 2001), its policy initiative for SMEs is limited to the fiscal measures in the climate change package of measures. Fiscal policies do indeed have a place in SME business management, however the hurdles for investment in SMEs are more related to bounded rationality (information deficit), principal agent problems (short term investment criteria) and moral hazard (lack of environmental awareness) (DeCanio, S., 1993). As well as environmental reasons there are economic reasons for giving priority to more efficient use of energy in businesses. The financial investments required to reduce energy demand are in some cases lower that costs for obtaining additional new energies (Dincer, I., 1999)

1.3 The effect of spatial planning on the use of CHP in SMEs

Many of the effects of climate change have been shown to be local or regional in scope (IPCC, 2000). There is therefore a better prospect for mobilising stakeholder interest and concern if climate change impacts can be demonstrated on the ground in familiar locations and businesses etc, than if impacts are analysed only at the national and international scales (Shackley, S., Fleming, P., & Bulkeley, H., 2002). In considering the relevance of community energy management in China, Sadownik B & Jacard M (2001), also focus on the premise that "*a significant proportion of future energy consumption would be pre-determined when urban form is designated within regional governance. Proper energy planning would therefore need to identify alternative energy opportunities that incorporate economic, social and environmental perspectives*".

The relevance of CHP to spatial management is widely promoted by the EC and has resulted in a raft of policy initiatives designed to encourage its use. The EC Directive on energy use in buildings (EC, 2002), the proposed CHP directive (EC, 2003) and the European Union Emissions Trading Scheme (EUETS) (EC, 2003) are all examples of the importance attached to CHP at the international level. The OECD and EU also recognised the importance of regional management by setting up Regional Energy Agencies and support programmes such as SAVE and Managenergy (www.managenergy.net). In the UK, The Sustainable Development Commission (SDC) is tasked to encourage a spatial approach to carbon reduction and development planning.

An area based scoping study reported to the Commission by the Tyndall Centre for Climate Change, had highlighted the limited approach to spatial carbon planning in the UK. The report also identified the need for new thinking on how incentives for carbon reduction can be provided by engaging small firms and local community groups (Shackley, S., Fleming, P., & Bulkeley, H., 2002)

The operation of CHP in the UK is not new. It was used in Manchester in 1911 for providing power to the local trams (CHPA, 1997). In the UK, after the Second World War, the newly nationalised electricity generating industry took the decision to site new power stations away from the centres of population, near coal fields and usually near large rivers or sea to make use of the natural cooling water (Eastop, T & Croft, D, 1996). In the 1980's, the Conservative Government sought to encourage the wide scale use of CHP through the 'Lead Cities' projects in Sheffield, Leicester and Tower Hamlets. Since 2001 the Government's Community Energy Programme has sought to encourage the use of CHP for larger community schemes, approving grants for public sector bodies such as Edinburgh University. Currently, UK Local Authorities do not have express planning powers to stimulate commercial energy efficiency in use. Councils, such as Woking Borough and Leicester City have however adopted supplementary regulations to encourage the use of Energy Service Companies (ESCOS) to develop CHP projects and have integrated the de-facto consideration of CHP into their planning process (Fleming P. & Webber, P., 2004).

1.4 The Environmental Impact of Small & Medium Enterprises in the UK

Various research studies have noted the uses of the term "SME" and the difficulties in any attempt to present SMEs as a homogeneous group of businesses (Curran & Blackburn, 2001:7). Detailed definitions of an SME were first provided by the Bolton Committee in their definition of small firms in 1971 and latterly in Section 248 of the Companies act 1985. The European Commission (EC) recommendation is based on the distinction within the SME group of businesses shown in Table 1.4 (www.sbs.gov.uk/statistics/smedefs.php).

Table 1.4 European Commission SME definitions

Max Criterion	Micro Enterprise	Small Enterprise	Medium Enterprise
No of employees	9	49	249
Annual T/Over	N/A	7 Million Euros	40 Million Euros
Annual balance sheet total	N/A	5 Million Euros	75 Million Euros
% owned by large company	N/A	25%	25%

The term SME is however used in this Thesis in an operational sense, by way of distinguishing a firm's output, level of decision-making autonomy and market size, from large businesses. This type of distinction is frequently made in the allocation of grant resources or state aids by the EC. In some cases it is sufficient that at least two of the criteria are verified for the definition to be appropriate to an organisation (DTI, 1998). National energy reports such as DUKES notes that CHP use in the small business sector is likely to be primarily for the provision of heat and electrical services in buildings and is recorded under the commercial or service sector listings. The use of CHP systems in SMEs therefore refers to use of small scale units in commercial or service sector enterprises.

The use of CHP in buildings is identified in three categories; commercial, public sector and residential buildings, as shown in Table 1.5, for the year 2002 (DT1, 2003a). The number and capacity of small scale CHP installations shown in Table 1.5 indicates a wide scope of use in commercial enterprises. This, in spite of costs and engineering complexity usually associated with the use of CHP systems (EST, 2001).

Table 1.5 Number and Capacity of CHP installations in buildings in 2002

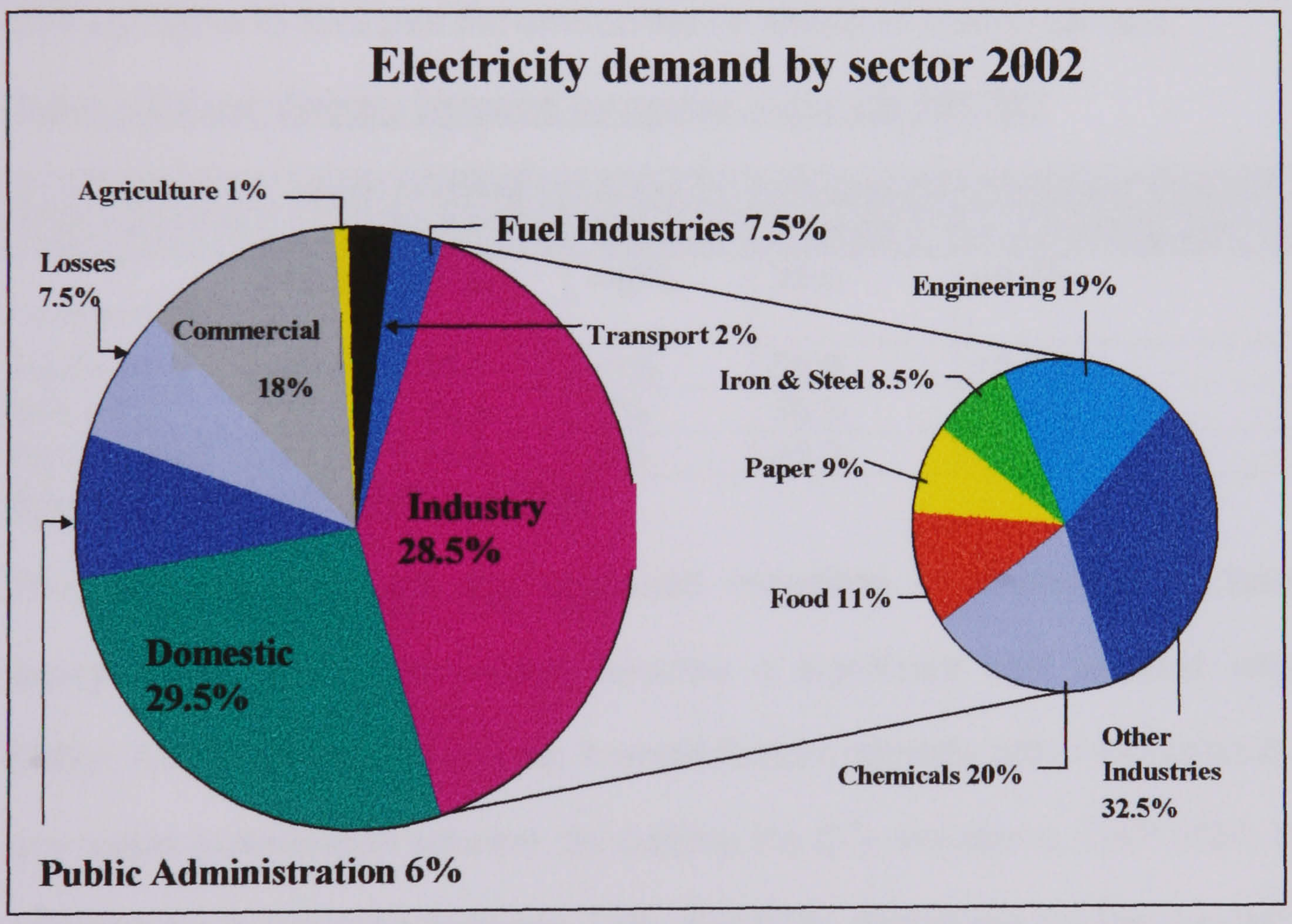
Sector	**Building Type**	**No of Schemes**	**Electrical Capacity (MWe)**	**Heat Capacity (MWth)**
Commercial	Leisure	435	42.4	69.9
Commercial	Hotels	303	37.6	63.5
Commercial	Offices	25	18.3	22.5
Commercial	Retail	8	5.8	4.6
Commercial	Other*	7	15.1	23.4
	Sub Total	**778**	**119.2**	**183.9**
Public	Universities	33	29.6	88.0
Public	Health	222	105.5	228.3
Public	Education	23	10.3	26.1
Public	Govt. Estate	14	11.1	17.8
Residential	Group Housing	51	46.3	86.3
	Total	**1121**	**322**	**630.4**
Commercial	**% of total Cap**	**69**	**37**	**29**

*Other: includes agriculture & airport buildings, source: DUKES (DTI, 2003a)

In particular, Table 1.5 shows a high level of CHP installations in the Leisure, Hotels and Office buildings within the commercial sector. This indicates the extent of the scope for increasing the use of CHP in the commercial sector, when the numbers of Leisure Centres, Hotels and Office buildings in the UK are taken into consideration. Christie I, Rolfe, H & Legard, R., (1995) emphasise the fundamental importance of SMEs noting that they are increasingly being considered important vehicles for economic regeneration and innovation.

The environmental impact upon communities of the operation of a business is therefore regarded as a central issue in the definition and practice of the corporate responsibility of many businesses. The environmental significance of the SME sector is also evidenced by its share of the national electricity consumption shown in Figure 1.3. The commercial segment representing the SME market is noted to have 18% of the electricity demand in the UK. The industrial sector, which accounts for 28.5% includes a proportion of small businesses, which are not separately accounted for in the DTI statistics.

Figure 1.3: UK electricity demand by business sector, end 2002



Source: Digest of UK Energy Statistics, DTI, 2003a

The importance attached to these figures is that at least 18% of the electricity demand is taken up by commercial enterprises, not large businesses, thereby offering scope for the use of small scale CHP in this business sector.

Research carried out by the Association for the Conservation of Energy (ACE) also indicate that energy consumption in shops, offices and other commercial buildings has risen by at least 65% since 1973 (ENDS: 309, 2000) and shows no sign of abating. The ACE also reported that energy consumption in the commercial sector is projected to grow at about 3.7% by 2010, which is far more than the growth in the industrial or domestic sectors (ENDS, 309: 2000). The final energy demand (Table 1.6) within the commercial sector is forecasted to be about 30.8 MTOE, again showing a proportion of 18% of the total energy demand in the UK. These data sets infer a considerable scope for the use of CHP by SMEs to minimise the environmental effects of energy demand.

Table 1.6 Final Energy Demand by sector in the UK (MTOE)

	1990	1995	Growth 1990-95	Forecast 2010	Forecast Growth 1995-2010
Commercial	15.0	21.0	+40%	30.8	+3.7%
Transport	45.5	46.9	+3%	58.9	+1.3%
Industry	33.2	32.4	-2%	38.9	+0.8%
Residential	41.6	49.6	-5%	45.3	+0.4%

Source: ENDS 309, October 2000

They conclude that with the continued imposition of environmental taxes, energy costs would increasingly become a significant cost element within SMEs. As an important resource, it would feature strongly within the context of any waste minimisation scheme. By curbing the CO_2 emissions, CHP offers the potential for a reduction between 13% and 57%, depending on the fuel being displaced (House of Lords, 1992). Therefore emissions savings from CHP are also significant to the UK, playing a leading role in meeting the Government's CO_2 targets.

Increasingly therefore, the environment and its business relationship should be a matter of great public concern for the SME business sector.

The challenge of a more extensive use of CHP therefore does not rest with its capacity as a suitable technology for mitigating climate change or security of energy supplies. It lies in its acceptance for use, particularly in the SME sector. A fundamental aspect about the CHP technology is that, no matter how technically or environmentally efficient it is if the end user does not acknowledge the financial benefits of its use, then the technology will become a symbol of the failure of the Government to encourage and motivate potential users.

Government policies, designed to encourage the use of CHP, have inadvertently resulted in contracting the market by the combined effects of regulatory and fiscal measures. The CHPA noted that *"Government claims that they have the policies to deliver 10GWe of CHP capacity by 2010 are, frankly, not credible*" (UK Power, 2003). CHP policy analysts have subsequently called for a new support framework in terms of *"the need to develop a decision-making*[11] *mechanism to be used as an internal tool for middle managers in businesses"* (COGEN, 1997).

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[11] Decision-making is a process that starts with the identification of a problem or opportunity and ends with a choice from a group of alternatives.

1.5 Drivers for decision-making process in Small & Medium Enterprises

For quite some time, academic commentators have been of the view that Government policies currently in place do not appear to have proved much of a motivation for SMEs to develop more environmentally sound management practices. A justification of this view is evidenced by a survey by the Mori Organisation and the University of Hertfordshire of business awareness of factors that influenced the environmental behaviour of SMEs (Table1.7). The results provide an indication of the low level of influence that environmental legislation has on the environmental performance of SME managers. The Government's task force on the business use of energy therefore sought to ensure that the environment was considered as an integral part of the business and prompted the Government to influence business environmental practices, through the use of economic instruments such as the Climate Change Levy (CCL)[12] and Landfill tax (ACBE, 1998).

Table 1.7: Environmental Regulations Identified by Respondents

Environmental Regulation	Positive Responses (%)
Special Wastes Regulations	17
Control of Substances Hazardous to Health	17
Packaging Waste Regulations	15
Environmental Prevention Act	12
Controls on emissions of Volatile Organic Compounds	6
Water Industry Act	6
Duty of Care Regulations	5
Integrated Pollution Control	<5
Environment Act 1995	<5
Landfill Tax	<5
Health & Safety Act	<5

Total Number of Companies Surveyed-288 ***Source: Hillary, 2000***

[12] The Climate Change levy is a structured tax on 17.5% Value Added Tax payers for the use of fossil based primary fuels and electricity.

The survey report noted that "*efforts by Government and business support organisations to raise awareness of the cost savings and competitive advantage that result from improved environmental performance have had little impact on SME behaviour*" (Hillary, 2000). Insufficient technical expertise to implement the technologies successfully has resulted in low levels of awareness of environmental issues and an acute lack of training capacity especially for SME managers. Achieving environmental awareness in SMEs is a therefore also a matter of training and capacity building, particularly from the higher education sector, for SME managers. Environmental training for SMEs where environmental responsibilities are not a distinct management function and the need for more appropriate vocational qualifications were also identified as priority areas by ECOTEC, in their strategic overview of the development of cleaner technologies[13] in the UK (ECOTEC, 1992). Noting as a possible explanation, that the reasons for the limited impact are both external and internal, Hobbs, A. (2000) affirms, "*External factors, such as policy, institutional and administrative systems, fail to encourage and support attempts* SMEs *make in this direction. Resource pricing and inappropriate subsidies often fail to encourage frugality in resource management. Internally,* SMEs *are usually small in capital and staff resources, frequently depend on simple labour-intensive and outdated technologies and are focused on short-term quick profit, if not day-to-day survival. They often lack long-term strategic vision and are insensitive to market changes. This is not a profile conducive to sustainable development*".

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[13] A conceptual and procedural approach to production that demands that all phases of the life cycle of a product or of a process should be addressed with the objective of prevention or minimisation of short and long term risks to human health and t the environment (Welford, R., & Starkey, R., 1996)

Hillary (2000) concludes that the reasons for the SME sector limited interests in environmental management may be expressed in either of the following:

(1) SMEs are aware of environmental management but hold a strong belief that it offers nothing for them.

(2) They are simply unaware of the issue and the entire concept of environmental management genuinely escapes them.

It is therefore apparent from a wide range of research studies over the last decade that SMEs constitute a significant proportion of the business sector. They have collectively a major impact on the environment but they present obstacles to change, preferring to "satisfice"[14] rather than maximise profits (DeCanio, S. 1993).

The conclusions of Hillary (2000), Hobbs (2002) and Decanio (1993) are all inviting a closer examination of the factors that affect decision-making in SMEs for the development of sound environmental practices. These are likely to be both external and internal. External criteria relate to Government and international regulations, internal factors relate to the culture of the organisational. With the separation of the external and internal factors influencing decision-making in SMEs, there is an indication of a complex decision framework for SMEs.

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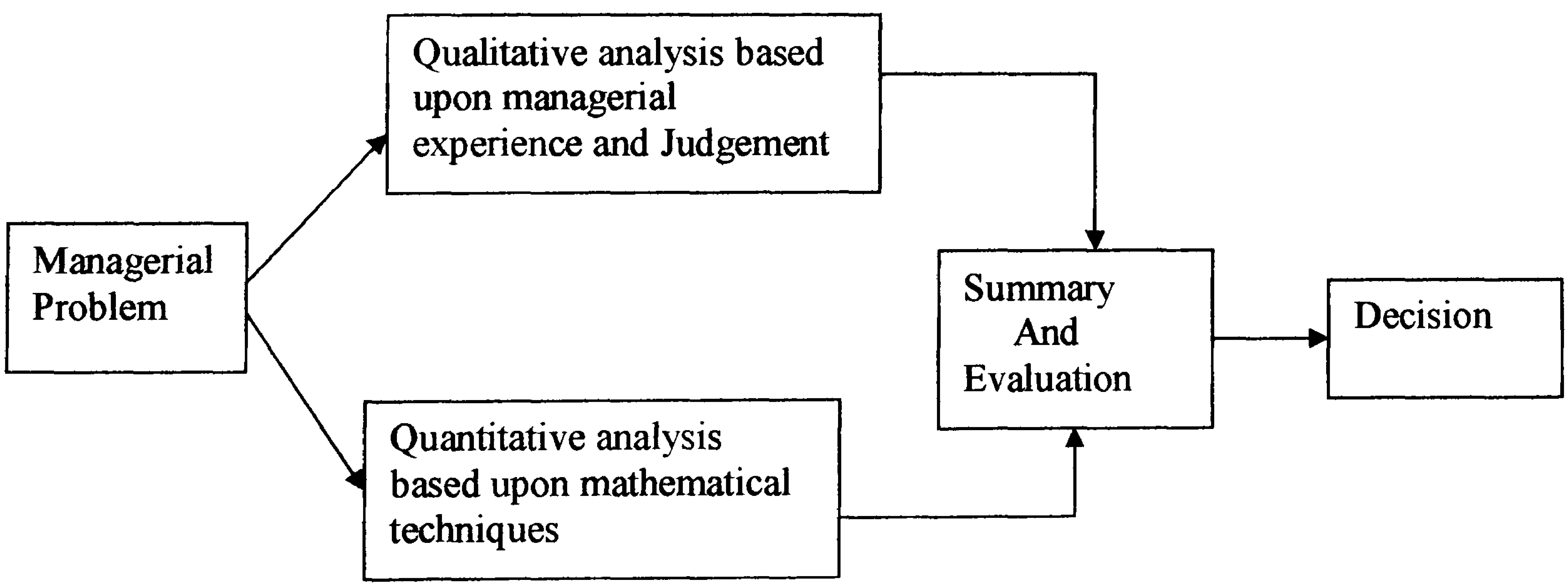
[14] This paradigm suggests that small firms resort to "satisficing" in a decision making process, where due to bounded rationality, approximation replaces exactness in reaching a decision (Simon, H., 1972).

This framework should link the internal criteria for decision making with those of the external criteria, (normally based on Government regulations and legislation), thereby offering the scope for an effective decision.

The manager responsible for making a decision or selecting a course of action will probably make an analysis of the problem in order to select the best decision or solution for the problem. This decision process is best understood by considering the flowchart in Figure 1.4. The qualitative process is based primarily on the manager's knowledge and experience. In the case of investment type decisions, quantitative analysis of the problem could also become a consideration in the manager's final decision. A key factor is the relative balance between the qualitative and quantitative analyses, which depends on the type of decisions being made, the managerial knowledge within the organisation and the decision-making culture.

Figure 1.4 A decision- making process diagram



Source: Anderson, D., Sweeney, D. & Williams, T., (1985)

Figure 1.4 is also a representation of a decision framework that is often located in a context of national environmental externalities and increasing sophisticated internal management practices. The need for such a coherent decision–making structure has led to a growing emphasis for Corporate Environmental Performance reporting (ENDS, 315 2001).

The framework in Figure 1.4 therefore suggests the need for a mechanism of business support, to link both the externalities and internal process in a way that assists in the process of decision-making on key environmental issues, especially those investment decisions relating to the use of technology. This mechanism could be in the form of a Governance Support System (GSS), which would potentially incorporate a Business Decision Support System (BDSS) set principally within environmental investment planning. Business support systems have traditionally been financial models using project appraisal techniques such as Cost Benefit Analysis (CBA).

Although financial models for assisting business decision –making have existed for a long time, almost without exception they do not assess the life cycle of products nor do they take into consideration external or socio-environmental cost factors (Bardouille, P. & Koubsky, J., 2000). Gold, B. et al., (1975) note that, whilst most existing managerial decision-making models translate each criterion affecting decisions into cost and revenue implications, there are a number of other key determinants in a decision process.

These key determinants are:

- Individual preferences
- Moving with the stream of change
- Organisational pressures

As well as the personal attributes and resources of individuals, external influences, i.e. social, economic and political also contribute to the decision-making process in small businesses (Bridge, S., O'Neill, K. & Cromie. S., 1998:63). The considerable importance of the individual's role in the decision-making process and the organisation's sustainable learning cannot therefore be overstated. Learning structures for environmental technology is already limited in the UK higher education sector as many of the technology and environmental courses are not structured to deliver real and practical problem–solving skills, relying on a bottom- up approach to learning with an emphasis on theory (Hale, M. 1995). The more complex and technical nature of CHP systems would therefore make it difficult for enough industry managers to be trained in order to make a significant impact on achieving the CHP target, by 2010.

The introduction of CHP into an organisation may also create staffing problems that were hitherto not there due to the need for training and new management structures. Bringing together a potentially complex arrangement of new management regimes, with staff implications, and ensuring the financial viability of the investment finance, would suggest a need for some form of assistance in the form of a new policy initiative or business support framework.

1.6 Significance and Justification for the Research

The concept of bounded rationality places a great emphasis on the role of the individual manager in an SME. As the decision making process within SMEs are influenced by external and internal factors (Section 1.4), a consideration of the internal decision-making processes in SMEs, would therefore seek to consider ways in which the individual decision maker could be motivated towards the use of CHP. The objective would be to identify ways in which managers can be positive drivers for CHP use in SMEs, by linking the economic, technical and environmental benefits. Hale, M., (1995:20) refers to this notion as a requirement for "*a methodology of technology assessment that stresses the approach that technology is the connecting link in the technology-environment-economic regeneration triangle*". A factor would be to express life cycle costs and therefore provide an incentive for business users to supply their own power.

Research commissioned by the Energy Saving Trust (EST, 2000a), had identified that an element of the SME sector, whose combined utility costs exceed £20,000 per annum could benefit from the use of CHP. The Carbon Trust's Action Energy program considers a minimum threshold of £50000 per annum. The EST study noted that only a proportion of SMEs could be targeted for the use of CHP, citing 200,000 in this sub category as high energy users. This is a large enough market element of the SME market sector, well above the 1919 sites (Table 1.2) estimated to meet the Governments CHP targets. The EST research concluded that, these SMEs have the potential to make a significant contribution to the national climate change target.

1.7 Purpose and Objectives of the Research

The purpose of this research is therefore to consider the necessity for a new policy framework to encourage CHP use in SMEs, one that would make CHP the acceptable equipment to use in an SME. Any proposed energy policy framework should be based on the principle of providing comprehensive energy services, with less use of environmentally damaging forms of energy. To achieve this, the framework would require a new type of governance, incorporating the use of fiscal instruments, to change behaviour. The Government's current strategy of introducing the Climate Change Levy has been shown to have limited effect (Section 1.2). Any consideration of a new policy framework should therefore include factors that would encourage a more integrated approach to environmental management, incorporating environmental performance as part of sound business practices.

The research study would be based on the need to understand the implications of CHP use in SMEs and to assess the specific requirements of SMEs in this regard. The research therefore sets out to achieve the following objectives:

(1) To assess the drivers and constraints for the use of Combined Heat & Power (CHP) systems in UK Small and Medium Enterprises.

(2) To assess the effectiveness of current Government policies towards increasing the use of CHP in Small and Medium Enterprises.

(3) To develop a new policy framework for encouraging the use of CHP in Small and Medium Enterprises.

1.8 Research Design

The structure of the research was designed with the intention of initially developing a conceptual (theoretical) "ideal" policy framework for CHP, based on a literature review including a critical appraisal of the Government's policy framework for CHP use in the UK. By the incorporation of data obtained from the research process, a new, practical and robust policy framework would then emerge. The research design therefore set out to identify the key areas to be tested in the research, as well as establishing guidelines and structures for the semi-structured interviews and questionnaire surveys.

The use of conceptual frameworks in the design of a research study is already tried and tested by many researchers (Bardouille, P., & Koubsky, J., 2000) Flexibility is however required in the development of conceptual policy frameworks and particular care has consequently been taken to allow for flexibility in any new framework developed from this research. This is achieved by considering in a separate, but linked way the external and internal decision-making criteria for CHP use in SMEs. Oakes. S, (2000), whilst promoting the use of conceptual frameworks in social science research also notes that "*the conceptual framework should allow for technical change as well an analysis of the actor oriented and contingent aspect of technical change as well as the structurally constrained aspects. The conceptualised framework should not make "a priori" distinctions among for example the social, technical, scientific and the political*".

The conceptual framework used as a basis for this research study is therefore designed to allow for these constraints. The qualitative data in the research was collected by desktop reviews and semi-structured interviews. Quantitative data was collected by statistical analysis of the national CHP database and from a questionnaire survey. The sample set was taken from those commercial enterprises that had installed CHP units within the 5KWe- 5MWe engine capacity. This category is noted in the CHP database (Ofgem, 2001b), as the limits of CHP engine sizes used by SMEs.

The sample set for the determination of the 331 SMEs was determined by sorting and formatting recorded data in the national CHP database to identify the characteristics of CHP use in SMEs. A distinction was initially made between SMEs and the large industrial type commercial enterprises. The structure of the research study was also prompted by the need to ensure integrity of the 'knowledge gained' in the research and its potential to provide useful inputs in the development of any new policy framework for CHP. Young, C. & Welford, R. (1998), in the development of a framework for environmental performance measurement for business, offer a theoretical framework for studying the decision making process in SMEs. This framework is amended as Figure 1.5, to offer a diagrammatic representation, as a further explanation of the structure of this research. Figure 1.5 shows a coherent relationship between the four phases of the process, with the results of a phase used to inform the design of the next phase. It shows the research process, in tandem with the research strategy for that phase and the outcome that is required.

Figure 1.5: A diagrammatic representation of the research process

	STRATEGY	METHODS/ PROCESSES
PHASE 1	• Literature review • Define aims and objectives	**Research Design** **Strategy**: Case Study **Purpose**: Determination of common factors in data sets **Method**: Desk-top exercise
PHASE 2	• Conceptualising a new policy Framework for CHP • Evaluating characteristics of SMEs that are conducive to CHP	**Research Design** **Strategy**: Analysis of national CHP database. **Purpose**: Evaluation of key characteristics of SMEs using CHP **Method**: Desk-top Computer based statistical analysis
PHASE 3	• Interview with policy makers • Surveys of existing CHP operators • Development of the Decision Support Systems	**Research Design** **Strategy:** Assessing the policy framework for CHP **Purpose:** Exploratory/Evaluation of previous data **Methods:** Semi-structured Interview, Survey questionnaire
PHASE 4	Developing the new policy Framework for CHP use in SMEs • Arguing the justification of the new policy framework • Recommendations from the research	**Research Design** **Strategy**: Analysis of Results **Purpose**: Determine of policy effects and inputs for Decision Support Systems **Method**: Computer based data analyses

Source: Adapted from Young, C. & Welford, R., (1998)

The methods used in the research were structured such that they were iterative in their approach, which allowed for the results of one method to be used to inform the design of the next stage of the research process (Figure 1.4). As such, the results of the research are slowly built up in the Thesis to allow for triangulation and for meaningful conclusions.

Of particular note is that "non-CHP" users were not surveyed and not interviewed. There were four reasons for this decision;

(1) Difficulties of objectively identifying a representative sample from non-CHP users i.e. a data set from the remaining 3.4 million SMEs/Commercial building users.

(2) It was felt that a more coherent approach was to determine "Best Practice" for the use of CHP rather than identify why it is not being used.

(3) The analysis of responses from non-users would be spurious, as they could have a wide range of reasons for not using the technology.

(4) The new policy framework is to be focussed on providing support for overcoming barriers; therefore discussions with those who had overcome barriers were deemed to be more relevant.

1.9 Structure of the Thesis

Chapter 2 offers a perspective of the strategic position of CHP within the wider discussion of sustainable development, resource efficiency & least cost planning. It also sets out its importance in environmental management for SMEs in a national & international context. It concludes that there is scope for reviewing the strategic perception of CHP in the UK, in order to meet new challenges in future energy scenarios.

Chapter 3 notes the particular effects of Transaction Cost Economics and Bounded Rationality in the decision-making process of SMEs. It sets out the arguments for justifying the use of Decision Support Systems as a mechanism for linking policy initiatives within a new governance framework. It concludes that such a mechanism would enhance the internal processes of decision-making in SMEs thereby encouraging the use of CHP.

Chapter 4 develops the argument for the use of Decision Support Systems as a basis for increasing its use of CHP by making a distinction between the technical considerations and the management considerations for CHP within SMEs. A conceptualised framework for the Governance of CHP is then derived from a diagrammatic representation of the existing CHP Governance framework and data from previous research studies. The Chapter concludes by expressing the need to further develop the conceptual framework with the results of new data collected in this research, within a context that allows its use by an easy transition from current practices.

Chapter 5 sets out the theoretical basis of the research methodology and provides a detailed description of the data collection by describing the four-stage data collection process. It explains how each stage of the data collection process informs and determines the design of the next method and consequently the tools used in the data analysis. Considerations of reflexivity, health and safety issues and ethics, were used to develop the argument for accepting the epistemological basis for the research design.

Chapter 6 presents the detailed results and the structure of their analyses. It notes the themes derived from the research, in particular; demand side management, financial planning, communication needs. It concludes that the current framework for CHP use by business is inadequate and that any new policy framework for CHP should be based on spatial management structures, set on a demand based decision support system and must offer additional economic benefits to SMEs.

Chapter 7 develops the discussion on the themes for a new policy framework and argues that the Government needs to employ a demand type policy framework as opposed to the current supply side policy framework for increasing the use of CHP. The new framework is to be based on a separate but linked Governance Support System (GSS) and a Business Decision Support System (BDSS). Both Support Systems designed to address the external and internal factors affecting the decision making process by SMEs.

Chapter 8 presents a system diagram of a GSS and develops an argument in support of the transfer of responsibility for CHP promotion to an area based governance structure and the benefits of using new forms of communication for achieving national targets. It also argues for an integrated governance structure for CHP and renewable energy technologies. The Chapter develops the structure of the new BDSS, based on marginal cost principles, life cycle analyses and the use of Decision support indicators as part of the decision making process. The Chapter concludes by discussing of the limitations of the Decision Support Systems and their potential use in performance reporting.

Chapter 9 discusses the potential effectiveness of the proposed policy framework for SMEs, within the changing role of Local Authorities and Devolved Assemblies. It discusses the potential role for Regional Development Agencies and ESCOS in assisting the use of CHP systems in SMEs in the implementation of Government policies on sustainable development planning. The Chapter identifies the scope for further academic work, noting the challenges and limitations of the GSS and the methodology used in the research. The Chapter concludes by claiming knowledge gained from the research as the development of an integrated policy framework for the use of CHP by SMEs based on a spatial planning and management strategy. It concludes that area based governance including new planning powers and finance regime would be crucial to any future policy framework for encouraging the use of CHP in SMEs.

1.10 Conclusion

The complexity and diversity of SMEs and their perceived reluctance to improve environmental practices could well lead to the inference that as the SME sector is not expected to produce significant amounts of CO_2 saving it therefore does not warrant much attention. This argument does not however offer credence when considering the environmental impact of SMEs (Section 1.3). A conclusion therefore must be that if SMEs are to make a contribution to improving the environment, as they have the potential to do, then a new framework for that contribution is worth developing. Any proposed policy framework should be based on the principle of providing a comprehensive structure for energy services, with less use of environmentally damaging forms of energy. To achieve this, the framework requires a new type of governance, one designed to change attitudes and consequently behaviour. The Government's current strategy for SMEs, based primarily on the use of fiscal measures has resulted in a steady decline of CHP use over the past three years (DTI, 2003a). The continued reliance on fiscal measures should therefore be a matter of concern for the growth of CHP in SMEs.

The justification for the research is therefore based on the potential contribution of CHP use by SMEs, in addressing the global challenges facing the UK and the international community (Section 1.1). This has in turn led to the aim of developing a new policy framework, which should encourage the greater use of CHP in SMEs. This aim is initiated by an examination of the effectiveness of the Government's policy framework for CHP towards the national CHP target.

The framework is to be designed as a cohesive structure, providing a link between the macro policy for CHP and the micro decision-making process within SMEs. Promoting the adaptation of CHP policies to those of climate change would therefore be an opportunity for increasing the use of CHP systems by SMEs. The importance of mediating factors, such as the framing of problems within a socio-political context and the knowledge base of SME managers, have been noted in previous academic studies as significant aspects of any study on social policy (Owens, S., 2000). The framing of a new public sector development structures such as the Improvement and Development Agency (IDEA)[15] is recognition of the need for an integration of business economic development within an area based governance framework.

The research design has therefore combined the use of Engineering, Economics and Social Science techniques and methods for data analysis as all three disciplines became relevant in the research. The approach is a reflection of the close interaction between Engineering and Economics, in any study of the social effects of the firm. Such an approach is postulated by social anthropologists such as Bruno Latour (1993) who notes that "*any study of science and technology must ultimately be contextualised within a wider ranging analysis of the dichotomous conceptualisation of nature and society as developed in Western Civilisation*". In order to do that, it is first helpful to understand the strategic relevance of the CHP technology, an appreciation of its environmental merit and the technical/economic barriers to its use.

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[15] An amalgamation of the Local Government Management Board and the Local Government Association

Chapter 2: The strategic value of Combined Heat & Power technology

2.1 Introduction

The challenges resulting from climate change and the need for security of primary energy supplies have frequently gained prominence over the global increase in the demand for electricity. In recent years, global demand for electricity has grown much more rapidly than for any other type of energy (IEA, 1998). This increased electricity demand would ultimately require a net increase in electrical plant capacity. Government statistics indicate that 91.2TWh i.e. 45% of the electricity produced in the UK in 1998, was from nuclear energy plants. In 2000, the proportion had reduced by 13% to 78.3TWh (DTI 2002a). This reduced proportion of nuclear electricity is set to reduce even further as plants are decommissioned over the next 20 years (Section 1.2). In this period the electricity demand in the UK is expected to grow by 1.5% (DTI, 2001b).

The reduction in nuclear electrical output is an indication of the need to examine cleaner energy producing technologies so as to minimise the effects of CO_2 from the probable fossil fuel plants that may be used to replace some of the ageing nuclear plants. The use of CHP could therefore be a key aspect of future planning for meeting the increased electricity demand. The limited use of CHP in the UK has been attributed to the inadvertent effects of Government policy initiatives as well as technical constraints (Section 1.2). Yet, there are many examples of the use of CHP in other European Countries, with particular governance structures for encouraging its use (Collier. R, & Lofstedt, U., 2001). This Chapter therefore examines the strategic position of the CHP technology and considers the barriers to its use within a UK and European context.

2.2 Waste Minimisation: The rational use of natural resources

The use of CHP by SMEs becomes more relevant to their business objectives when discussed in the context of waste minimisation. The concept of waste minimisation refers to the reduction of waste at source through the understanding and changing of processes to reduce and prevent waste. This is also known as process or resource efficiency. Waste minimisation strategies relating to energy use are generally based on a principle of carbon neutrality, i.e. a system that does not produce any more CO_2 than it replaces. It operates on a waste hierarchy, which is based on the three "Rs":

- Reduce
- Reuse
- Recycle

Waste minimisation in this context therefore seeks to focus on reducing raw materials or primary energy inputs at source and promotes a long-term perspective for environmental protection. The Producer Packing Regulations (DEFRA, 1997b: 2000a) is an example of the importance attached by the Government to sound waste management practices. Waste minimisation for energy efficiency takes two distinct forms, generally labelled 'soft' measures and 'hard' measures. 'Soft' measures refer to the more cognitive aspects of waste minimisation and involve little physical interference in the way the primary energy is used or converted. 'Hard' measures are more interventionist and refer mainly to the installation of technological systems and control mechanisms, they therefore have a greater potential to reduce CO_2 levels relative to softer measures. Examples of these measures are shown in Table 2.1

Table 2.1 Comparison of Soft and Hard Energy Efficiency Measures

Soft Measures	Hard Measures
Energy Auditing	Heat Pumps & Fuel Cells
Tariff Analysis & Fuel Switching	Condensing Boilers
Metering, & Controls Improvement	Combined Heat & Power Systems
Energy Monitoring & Targeting	Wind/Solar/Biomass Systems

Source: Eastop, T. & Croft, D., (1996)

The Government has used the changes to the Building Regulations (DEFRA, 2000c) as a means of encouraging the adoption of the softer energy efficiency measures during the refurbishment and new build of commercial buildings. The European Commission Directive on Energy Performance of Buildings, (EC, 2003), is also designed to ensure that soft measures should always be considered in advance of any hard measures.

This research is therefore conducted on the premise that all energy saving potential for soft measures has been a perquisite for the businesses considered in this study. There is the growing realisation that the use of soft measures alone would not achieve the levels of CO_2 reduction required. In addition, they do not meet the challenges of sustainable energy development on such issues as efficiency of production. The role of the SME sector, with 99.8% of the businesses in the UK therefore becomes a significant factor in its potential for energy savings (Hilary, R., 2000).

Table 2.2 shows that energy consumption in the commercial (SME) sector is projected to grow by about 3.7% of 1990 levels, by 2010, which is far more than the growth in the industrial or domestic sectors (ENDS, 309: 2000).

Table 2.2 Final Energy Demand By Sector In The UK (MTOE)

	1990	**1995**	**Growth 1990-95**	**Forecast 2010**	**Forecast Growth 1995-2010**
Commercial	15.0	21.0	+40%	30.8	+3.7%
Transport	45.5	46.9	+3%	58.9	+1.3%
Industry	33.2	32.4	-2%	38.9	+0.8%
Residential	41.6	49.6	-5%	45.3	+0.4%

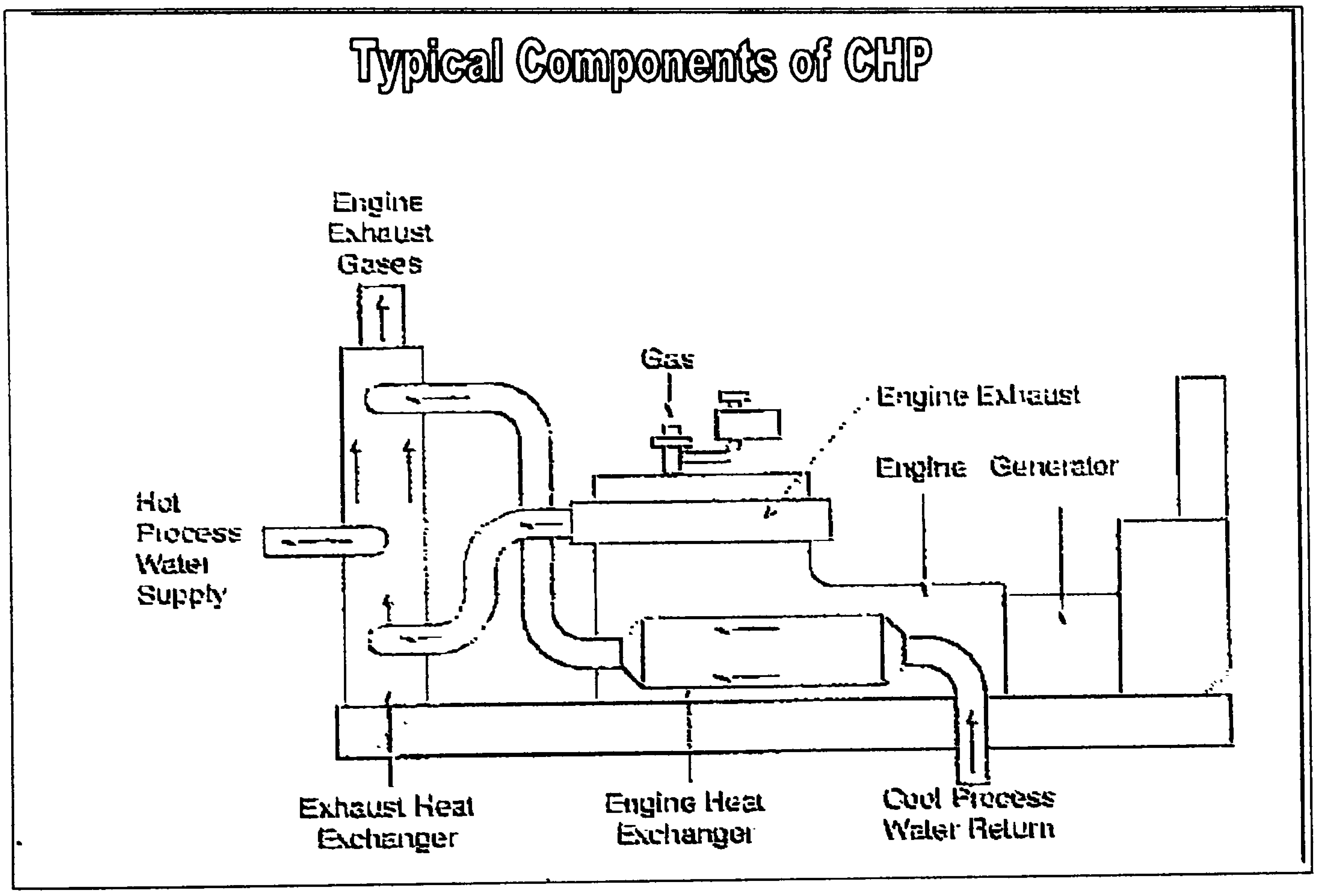
Source: ENDS 309, October 2000

The 1998 White Paper describing the new role of the DTI, noted that SMEs were fundamental to a dynamic and growing economy. As the trend continues towards the globalisation of International economies, it has become more evident that SMEs are being considered as important vehicles for economic regeneration and technical innovation (Christie, I., Rolfe, H. & Legard, R., 1995). In addition, SMEs have an important local and regional significance as they define the skills base and prosperity of the area. SMEs therefore feature significantly in the development aims of the Mayor of London as a means of regenerating the London economy (LDA, 2000:37). This is a recognition that markets of independent SMEs are often localised, thus making them an important phenomenon within a local context.

2.3 The Combined Heat & Power Technology

The main component of a CHP unit is a prime mover (a gas or diesel reciprocating engine or steam turbine), driving an alternator that produces electricity. Other elements of the plant include a heat recovery system that recovers the heat from the waste gases in the form of hot water or steam (Figure 2.1)

Figure 2.1: Schematic Diagram of a Packaged Small-Scale CHP System



Source: Future Energy Solutions (FES), 1997b

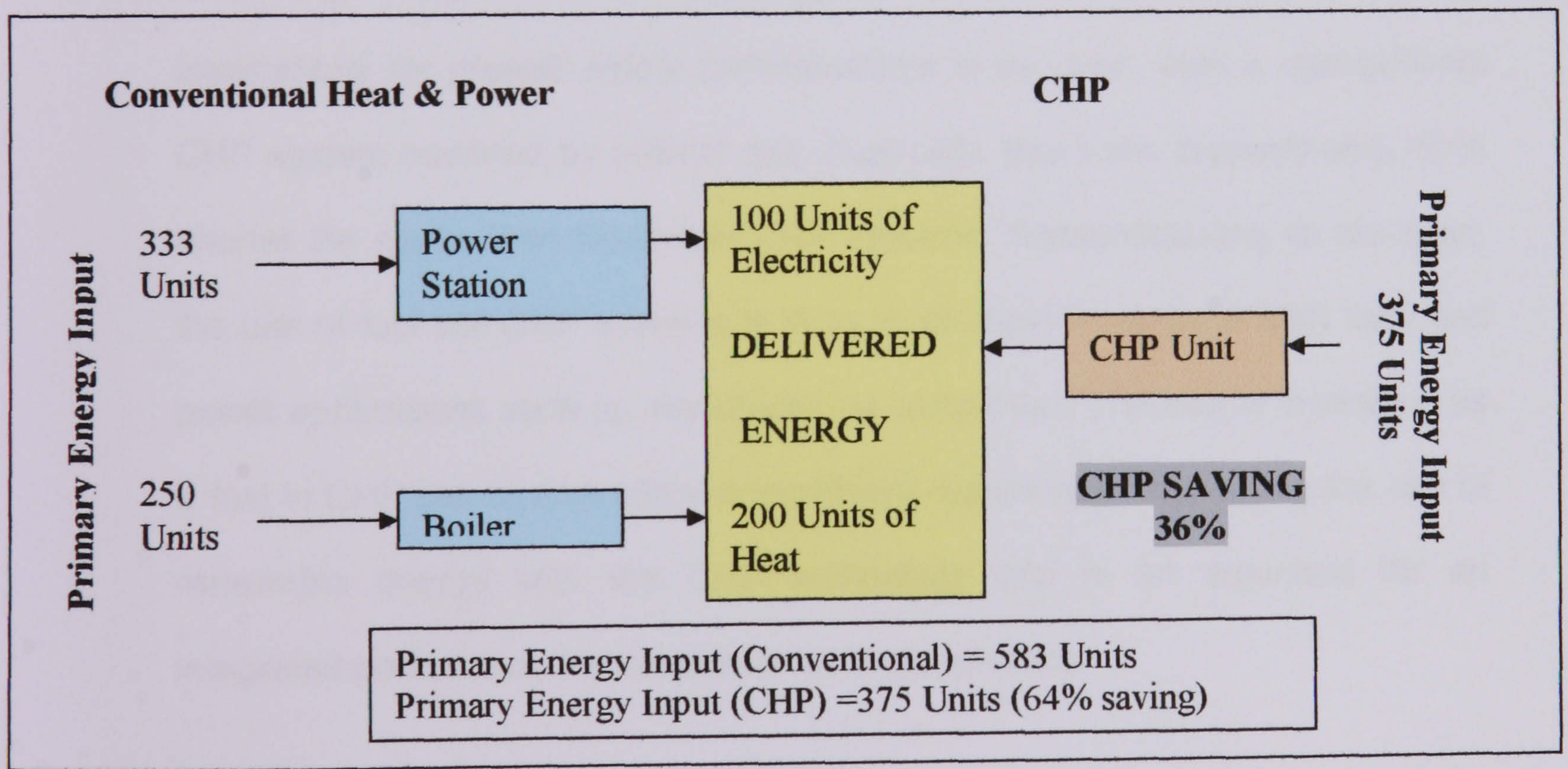
In addition, the heat produced by a CHP plant can also be utilised to meet the cooling load using absorption chillers. This means that a CHP plant can be operated cost effectively throughout the year offering a significant benefit as a response to the mitigation of greenhouse gas production. Although the installation of a CHP plant involves a significant financial investment, payback is generally achieved in five to six years (FES, 2003).

The physics of electricity generation unavoidably results in low-grade heat as a by-product. The heat is therefore difficult to sell from large power stations, generally due to the long distance from the populated and industrial centres. In most conventional power stations, some 65% of the heat produced by burning fossil fuels is usually lost via the cooling towers and hence they are only about 35% efficient. In contrast, site based generation of electricity provides an opportunity to use the heat generated in the process and, as a result, the overall efficiency of fuel utilisation can reach around 90%. It is this gain in efficiency of fuel utilisation that leads CHP to being cost effective and significantly more environmentally efficient. In commercial buildings (usually occupied by SMEs) the adoption of a combined production of the space heating, hot water and electricity from a single system therefore offers considerable potential for waste minimisation. Traditional CHP markets for commercial buildings are those with high heat demand e.g. Manufacturers, Leisure Centres, & Office buildings.

CHP systems are now frequently located where the heat can be used, as this has been made more acceptable by the development of cleaner gas-fired generation plants. In a CHP system, useful heat is delivered at a relatively high temperature that also results in electricity being generated. Heat is therefore available on site either for process or space heating. Therefore within a CHP system design, it is possible to optimise the heat and electricity output to meet the particular site requirements. Small CHP systems, from 5KWe up to 5 MWe, are most commonly used by SMEs for electricity, space heating and hot water for cleaning/washing processes.

These CHP systems utilise an internal combustion engine burning natural gas or oil. Normally developed as a complete package, they are relatively simple to install in existing boiler rooms, effectively replacing the main boiler. These can be linked to suitable heat loads in public and commercial buildings, industrial sites and district heating schemes. Good maintenance planning is essential for any CHP system to achieve its energy benefits. A highly efficient energy conversion process is the main claim for the benefit of the technology (Figure 2.2). As CHP plants are typically much smaller than conventional power stations, they are frequently sized to meet a site's electricity and heat/cooling demand. Sizing of a CHP plant would also include an assessment of the economic value of the financial/organisational costs of project development.

Figure 2.2 Comparison of conventional heat & power production with CHP



Source: Response to the DEFRA discussion document on climate change, CHPA, 1993

In the USA, there is growing emphasis for research on new types of CHP systems such as Fuel Cells CHP and Hydrogen based CHP. The potential for integrating CHP and renewable energy technologies, such as wind and biomass systems in order to achieve an improved overall reliability in both systems is also being examined (Peck, D. and Chestnut, J. 2002). Within the UK, the benefits of using micro-CHP in individual domestic premises, has been identified in the CE review (CE, 2002) and is included in the Government's target for CHP use in the UK. With the introduction of micro CHP, there is potential for domestic and smaller commercial boilers to be replaced by micro CHP so that the benefits of local production of heat and electricity can be achieved. The CE report does however offer little scope for micro CHP in the period leading to 2010, due to the delays in introduction of "nett metering"[16] technology. Fuel Cell CHP technology is still relatively expensive and has implications for greater safety considerations in its uses, than a conventional CHP system powered by natural gas. Fuel cells also have approximately 50% shorter life spans than fossil fuel CHP systems. Notwithstanding its life span, the use of fuel cell CHP systems is likely to increase in areas of high heat and power applications such as manufacturing companies. The use of Hydrogen as a fuel in CHP plants also offers a significant opportunity for merging the use of renewable energy with the CHP technology and is an argument for an integrated governance framework for CHP governance.

[16] This metering system allows the offset between power produced locally (in the home) and power bought externally, within a single metering system.

The economics of using CHP systems are site specific and normally based on:

- The site's energy demand profile; Capital and maintenance costs,
- Plant operating hours; primary value of the input and output utilities.

There are inevitably a number of differences associated with CHP systems as compared to conventional electricity production or boiler only systems as shown in Table 2.3, identified as positive and negative aspects of CHP schemes.

Table 2.3: Positive and Negative Attributes of a CHP Scheme

Positive Attributes	Negative Attributes
Reduces primary energy use by about 36% compared to power station	External electrical feeder systems may need reinforcement
Reduces electrical losses	Perception of low reliability of plant
Offers security of supplies on sites	More expensive compared to a boiler
Much better investment where plant is required in excess of a six year life	Maintenance costs are higher than other heating sources
Reduces Greenhouse gas emissions by 40% compared to a power station	May require an interface with the external electricity network.

Source, Eastop & Croft, 1996

These attributes are not applicable to all CHP installations but are provided in this Thesis as an indication of the issues that are being encountered by CHP operators. Maintenance planning is noted as the key to an effective CHP system performance and hence it's ability to offer environmental benefits. The form of procurement and the decision processes that lead to that procurement are also vital elements in the operational effectiveness of a CHP installation (Strachan, N. and Dowlatabadi, H., 2000).

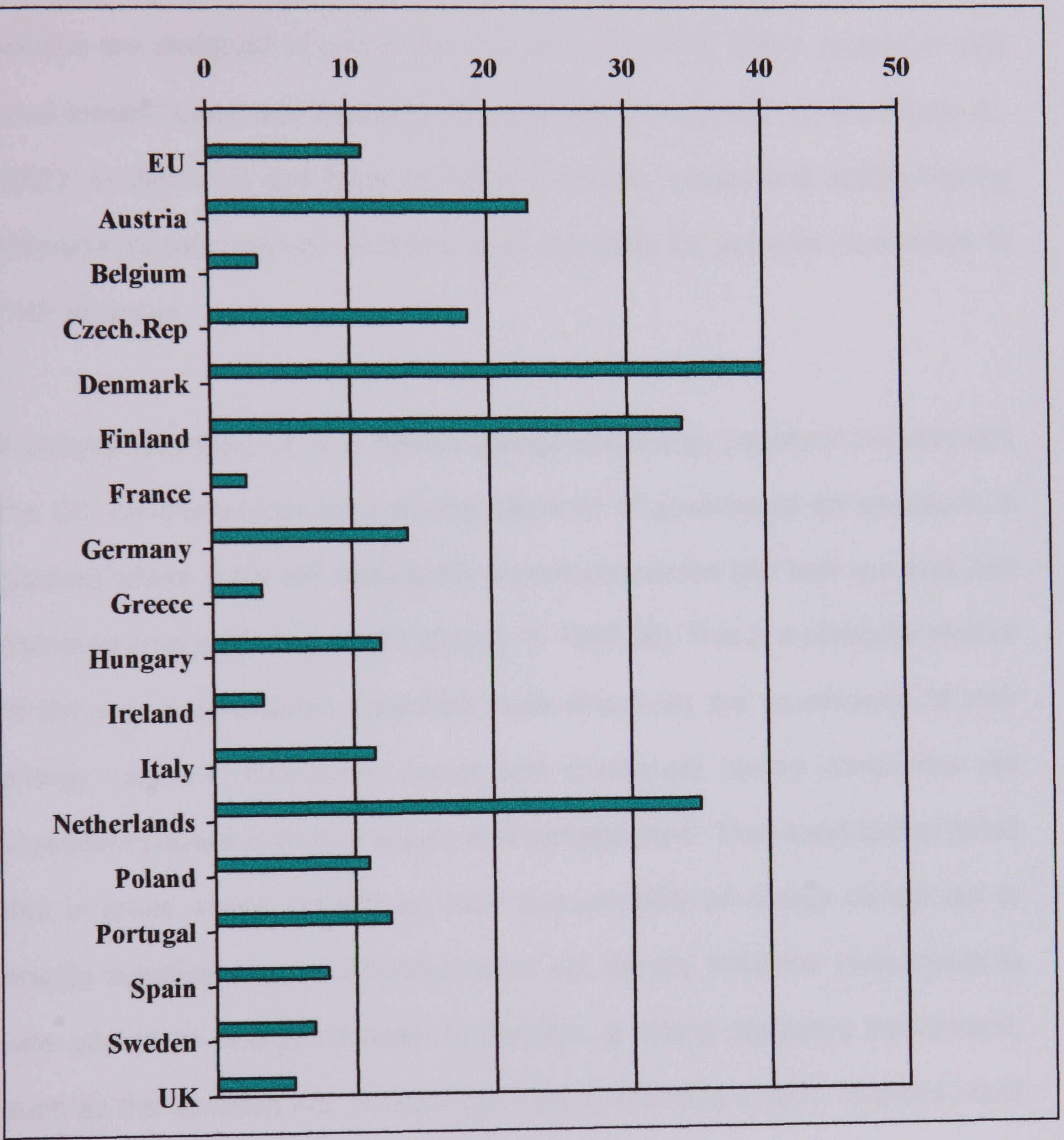
2.4 The use of Combined Heat and Power in other European Countries

EU member Countries are consuming more and more primary energy sources and importing more energy products, making them extremely dependent on external supplies (EU, 2000b). Current estimates are that the EU imports some 50% of its primary energy requirements. This is expected to rise to 70% in 2030, with 50% of those imports expected to come from the Middle East.

With the use of coal declining, a scenario could therefore be envisaged of an increased use of oil and gas for power generation in the EU. Moreover, with the increasing concerns about the environmental effects of de-commissioning, it is unlikely that future electricity production capacity would be provided by nuclear power. Power generation would therefore be by gas/oil-fired stations, leading to increased CO_2 production. The sphere of direct influence of the EU would be, to manage the potential increased electricity demand by encouraging the more efficient use of primary energy resources, through the use of energy efficient technologies such as CHP.

Many Western European Countries notably Denmark and the Netherlands have therefore developed specific policies for encouraging the use of CHP as part of a governance framework involving regional energy authorities and national Governments. The extent to which CHP is used in other European Countries is shown in Figure 2.3.

Figure 2.3: Percentage of electricity supplied by CHP in European Countries, at the end of 1999.



In Ireland, limited natural gas resources and a number of largely political and economic barriers have constrained the use of CHP to only 1%-4% of installed electricity generation capacity (COGEN, 1998). In Sweden and Finland, specific policies are designed to encourage the use of CHP by SMEs as part of their drive towards clean and economic energy production (Collier, U. & Lofstedt, R., 1997). In Germany and parts of Eastern Europe, established district-heating networks already provide sufficient heat demands for potential conversion to CHP schemes.

A comparative study of local climate change and energy policies in Sweden and the UK, concluded that the potential influence of governance on emissions is greatest where there are municipally owned companies that both produce and distribute energy (Collier, U. & Lofstedt, R. 1997:38). This is a particular feature of the way Scandinavian Countries have structured the governance of their energy supplies. The public sector and municipally owned companies are significant players in energy supply and management. The report further noted that in areas where there is no local accountability of energy companies or energy supplies, Local Authorities could not directly influence investments in new and clean energy capacity. In Sweden, a strong legislative background, such as the Swedish Act of Municipal Energy Planning (1977), required Local Authorities to develop a Municipal Energy Plan.

The European Union strategy for energy management for the period up to 2020 is largely based on the use of gas turbine combined cycle plants and small CHP plants as a replacement for the declining use of oil and coal burning plants (EU, 2001b). In particular the report refers to an "*expectation for improvement in the efficiency of power generation, due to the combined effect of adopting more efficient technologies such as CHP and the increased use of renewable energy sources*".

An EU wide research study by the International Project for Sustainable Energy Paths (IPSEP) noted that the contribution of CHP to reduced greenhouse gas emissions in the EU is currently grossly underestimated (IPSEP, 2000). The overall result of the study was the suggestion that the EU could cut its carbon emissions by half over a thirty-year period, while saving money and creating jobs, provided that they implement a series of innovative, least-cost oriented energy policies. Before Kyoto in 1997, the EC had estimated that the use of CHP could enable the EU to avoid 150 Mt of CO_2 emissions. At the Cologne Summit in 1999, the EC presented lower estimates of 57 Mt of CO_2 (IPSEP, 2000). Focusing only on plants to be built in 2000-2020, the IPSEP study estimates that as 75-90% of additional electrical capacity would be built as CHP plants, CHP would therefore contribute to 58-69% of the total EU wide thermal power generation in 2020. This would have the effect of a reduction in CO_2 emissions by 290-350 Mt a year and is to an extent a contradiction of the EC reports about the potential use of CHP to reduce CO_2 emissions.

2.5 Combined Heat & Power in the context of sustainable development

One of the two treaties signed at the 1992 Earth Summit in Rio and which formed the basis of the Summit in Johannesburg, South Africa, in 2002, is generally referred to as "Agenda 21". The underlying principle of this agreement is sustainable development. The term sustainable energy development is sometimes used synonymously as sustainable development to suggest a greater emphasis on the energy efficiency aspects of sustainable development. This Thesis derives its definition of sustainable development from the Bruntland report, as "*the ability of the environment to supply raw materials and assimilate waste, whilst maintaining biodiversity and quality of life*" (WCED, 1987).

The vital aspects of sustainable development are the setting of targets, devising indicators to keep track of progress and reporting in a way that is clear, comprehensive and useful to the wider audience. Some environmental commentators suggest that in order to achieve sustainable development, new policy approaches are required for public participation, institutional change and partnership building as envisaged in the Local Agenda 21 agreement (Burgess, J., Harrison, C. & Filius, P.,1998). Sustainable development principles also point out that external, social and environmental consequences arising from production systems must be taken into consideration in decision-making at all levels of business (Bardoiille & Koubsky, 2000). The Bruntland definition of sustainable development does however have limitations in its implications for SMEs primarily because it does not offer a time dimension and is vague about the definition of the environment (Bartelmus, P. 1994:69).

Nonetheless it has been a useful starting point for a discussion of the relationship between human consumption and economic growth leading to the stringent environmental concepts of bio-regionalism[17] and permaculture[18] (Hutchinson, A. and Hutchinson, F., 1996). The concepts of bio-regionalism and permaculture have subsequently become merged into the term "eco-sustainability", as a synonym for sustainable development, which closely mirrors the use of and interaction with the regional and local ecological footprints and allows for a more focussed understanding of the underlying principles of sustainable development policies (Hutchinson & Hutchinson, 1996).

The concept of sustainable development recognises that economic growth and environmental protection could be made compatible, but that this would require quite radical changes in economic practices throughout the world. It is clear that new forms of co-operation between Government, business and society would also be required to achieve this goal. Before attending the 2002 Earth Summit in Johannesburg, the UK Minister for the Department for the Environment, Food and Rural Affairs, Margaret Beckett, also referred to sustainable development as fundamental to the future of a global society and called for a committed and co-ordinated action, as an outcome of the Summit (PRASEG, April, 2002).

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[17] Sustainable Development based on Bioregionalism fosters a sense of place, a respect for sentient beings. It replaces the consciousness of place community and food security.

[18] Permaculture is a way to make conscious decisions to redesign our lives manage our resources well and reduce waste (Hutchinson and Hutchinson, 1996:338).

DEFRA (1996) notes the key sustainable development objectives for the UK as;

- To ensure supplies at competitive prices;
- To reduce adverse impacts of energy use to acceptable levels;
- The efficient use of natural resources;
- To encourage consumers to meet their needs through improved waste minimisation techniques[19].

These objectives underpin the Government's environmental strategy for meeting its environmental commitments made in Kyoto and have led to the development of targeted policies for achieving positive indicators in the future. Some of these policies were first set out for public consultation in the climate change consultation document (DEFRA, 1998g). At the heart of the consultation exercise was the need to develop a concerted effort of the efficient use of natural resources (especially fossil fuels) and the practice of waste minimisation techniques, noted in Section 2.2.

[19] Waste minimisation techniques have particular resonance for CHP, as they include concepts of energy efficiency, resource management and sound environmental practice

2.6 National policies for Combined Heat & Power systems in the UK

The important role of CHP in meeting the domestic CO_2 targets was first noted by the Government in its climate change consultation exercise in 1999 (DEFRA, 1999g). The policy instruments that embodied the climate change programme were therefore meant to deliver the Government's climate change objectives. They were also meant to be a test of the Government's CHP credentials and its ability to take radical steps in meeting its objectives.

The main reason for the decline in CHP capacity has been attributed to the introduction of NETA (Section 1.2) as wholesale electricity purchase prices fell by about 40% of 1990 levels, in 2002. There is therefore little incentive for electricity users to consider supplying their own power from a small scale CHP system. NETA therefore had a highly detrimental effect on the financial viability of the use of CHP by SMEs, being unable to accurately predict power output in advance. ILEX (2003) noted the problems for CHP use under NETA as:

- NETA was designed with large electricity producers in mind and therefore offered little flexibility for small scale power producers.
- The increase risk of exposure to imbalance charges[20]
- The penal nature of the imbalance charges due to irregular outputs
- The reduction in financial embedded benefits[21] and the need to negotiate with a supplier to realise some of these financial benefits.

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[20] Imbalance charges are charges resulting from the difference between predicted outputs and actual outputs in a given supply period (ILEX, 2003)
[21] Embedded benefits is the generic name given to the various benefits that arise from distribution-connected generation (ILEX, 2003)

In a sense, the installation costs and the risk of future financial penalties were high in comparison to the outputs levels for fluctuating electricity production from CHP systems or from renewable energy sources. The structure of NETA therefore discouraged new CHP users, particularly for small scale CHP. As a policy instrument, NETA was designed to reduce the cost of electricity to consumers whilst also addressing industrial competitiveness (DTI, 2000a). It had a significantly negative impact on the renewable energy, CHP and nuclear energy industries resulting in electricity production by nuclear energy declining by 14% in 2000 when compared to the previous year (DTI, 2002a).

Ofgem however reported that "*the results of its annual review of NETA showed that smaller generators (CHP and renewable energy) do not seem to have been disproportionately affected by the lower electricity prices resulting from NETA*" (Ofgem, 2002a).The response from the CHPA was to lay the blame for the problems of the CHP industry squarely on the NETA, noting "*sales of CHP have fallen by 40% since NETA was introduced in 2001, noting a 23% decline in wholesale prices for CHP electricity*" (CHPA, 2002).

ILEX (2003), does not however lay the blame for the sharp decline in the CHP fortunes only on NETA. They note that "*at the time NETA was introduced in 2001, there was an over capacity of electricity producing plants in the UK and a diversity of ownership of power stations*". Therefore competition in price stemming from plant over capacity may also have contributed to the decline in electricity prices.

In discussing the effects of NETA on the CHP industry, the PIU review noted the overriding importance of meeting the Government's CO_2 targets by a recognition *"that there should be no single automatic mechanism in place to ensure that the UK meet its Kyoto target, if events do not turn out as expected. For this reason, it is crucial that energy sector developments continue to be monitored and that the assessment of new policies takes account of any contribution they might make to the CO_2 target or to the extent that they might make it harder to meet* (PIU, 2002). Consequently concerns about the potential shortfall prompted the Government to set up a series of additional policy instruments, such a relaxation of the criteria for claiming the Climate Change Levy (CCL) for CHP schemes to encourage the its installation. The Government also took further powers in the Utility Act, 2001, to allow for the introduction of additional fiscal measures, should it feel that they were required. These actions were all geared to send a message to the CHP industry of their commitment to encourage the wider use of CHP systems.

In the larger industrial sector the Government has encouraged the use of voluntary strategies for reduction of energy use (DEFRA, 2000b). This has been linked to the Integrated Pollution Prevention Control (IPPC) system, which imposes financial penalties for exceeding emission limits. The current UK Emission Trading System (UKETS) and the proposed European Emission Trading System (European Commission, 2001a) are also directed at utility producers and large industrial organisations offering incentives for the reduction in the emission of greenhouse gases (Grohnheit, P., 2003).

The Community Energy Programme continues to offer financial incentives for CHP use in the domestic sector. There are however no grant programmes supporting the installation costs of CHP systems in the commercial buildings, although the Action Energy Programme does provide financial assistance towards consultancy services for CHP project appraisals. The relevance of grant programmes to this Thesis is that there is currently a basic requirement for about 1919 small scale CHP sites between 500KWe and 5MWe with a total required capacity of about 35.4MWe in order to achieve its target by 2010. This Thesis therefore focuses on the SME sector, in the recognition that there are well-defined strategies in the UK for CO_2 abatement in the industrial and the domestic economic sectors.

There have been two key Government ministries with some responsibility for CHP. DEFRA has a distinct mandate to promote Energy Efficiency and the policies relating to climate change. The DTI is responsible for the promotion of technology and competition including CHP. Future Energy Solutions (FES; formerly ETSU) and the Carbon Trust (CT) currently have joint management for energy technology programmes. Certainly there is scope for much duplication and overlap as FES appears to be acting as a delivery agency for the CT, who are mainly policy strategists for the management of the Action Energy Programme. Reduced electricity prices have undermined the economic case for CHP in SMEs and fewer CHP schemes have consequently been installed since 2001(DT1, 2003). This, in turn, makes the Government's domestic CHP target for 2010 less likely to be achieved.

2.7 Institutional barriers to the use of Combined Heat & Power in the UK

In a report on the barriers to Combined Heat and Power in Europe, a number of factors that were considered key obstacles in inhibiting the increased uptake of CHP in Europe generally and the UK in particular, were highlighted (CHPA, 1995). These were stated as:

- **Economic**- these were factors that limited the payback of CHP schemes, either by limiting the income derived from the sale of heat/electricity or the cost of the inputs fuel or equipment.
- **Regulatory**- Relevant issues here include the ability to 'wheel' fulfilling technical requirements, licensing arrangements, etc (Wheeling relates to the level of freedom that firms have, to install CHP).
- **Institutional**- Relevant factors include the role and attitudes of electricity utilities and the value governments place on environmental protection.

They are manifested in the following recurring themes:

- Tariffs for surplus electricity sold to the grid are too low.
- Tariffs for standby power and in particular back-up power supplies to the co-generator can be very severe.
- The freedom to move the plant is rarely allowed and when it is, it is usually too expensive to consider.

Attempts to remove some of these barriers have inadvertently created new barriers such as is evidenced by NETA. Other barriers are mainly due to the difficulties of Embedded Generation[22] practices in the need to sell surplus electricity to the national distribution network.

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[22] Bedding or localising the generation of electricity such as with small-scale CHP.

There has been considerable scope for the RECs to limit the application of CHP schemes as part of their role to regulate the electricity that is received by their local network. Distribution networks in England and Wales have long been criticised for failing to recognise fully, or to reward, the contribution that Embedded Generation could make to the efficiency of the operation of electricity network (CHPA, 2001). The recognition that the installation of Embedded Generation capacity can delay or even offset the need for network reinforcement appears to be lost on the RECs. At the operational level Embedded Generators can also provide valuable network services such as offsetting reactive power, improving frequency responses and island mode operations (CHPA, 2001). The circumstances that give rise to some Embedded Generation problems are complex and have their roots in the original ownership structure of the electricity industry.

The Government in recognising the conflicting concerns of the RECs and the embedded generators set up a joint industry working group, in 2000 to identify some of the key issues of concern that may be preventing an increased use of embedded generators. The Embedded Generation Working Group report, noted the following key recommendations (OFGEM, 2001):

- OFGEM should review the structure of regulatory incentives on RECs in the light of the new statutory duty on RECs to facilitate competition.
- A new group should be established to co-ordinate and take forward the implementation of the present group's recommendation.

Various solutions proposed in a further consultation document by the working group may eventually lead to a further deregulation of the electricity supply industry (OFGEM, 2002) if accepted by the Government. Some of these solutions suggest a further fragmentation of the responsibilities of the RECs to allow a less hostile attitude to CHP. Such a scenario may be of considerable benefit to CHP schemes, as the current financial disincentive for a CHP system to be connected to the grid network could be removed.

Any attempt to further decouple the sales and distribution responsibilities of the RECs, may however lead to concerns about how far the Government should go towards supporting Embedded Generation and of the viability and long-term protection to the electricity industry. The main concern would be the security and integrity of the electricity network and the ability to guarantee national electricity supplies. The RECs may claim an inability to meet their long-term financial commitments, and that in turn, would lead to frequent power failures.

2.9 Conclusion

Concerns stemming from studies relating to security of energy supplies, climate change and the increased demand for electricity, have all been catalysts for long term scenario speculation by energy professionals (Section 2.4). These studies, carried out both at national and international levels, have broadly converged on similar conclusions, i.e. the need for increased use of CHP. An example of such a study is the PIU review (2002), which concluded that the most cost effective policy drive for the Government in the next twenty years would be to improve technical energy efficiency. These stretch from improving insulation, to using far more Combined Heat & Power and Renewable Energy Technologies in the manufacturing industries and Small Businesses. The Government's Energy White Paper informed by the PIU conclusions also re-affirmed the CHP target stating "*We remain committed to a target of 10gWe of good quality CHP capacity being installed by 2010*" (DT1, 2003).

A study of the future of CHP in the European market (COGEN, 2000) estimates the potential capacity of CHP to increase by some 40% by 2010. Within a scenario that the total EU carbon dioxide emissions would be greater in 2010 than in 1990 (mainly due to the inclusion in the EU of the Central and East European countries by 2010), the report concludes that "*CHP is the best option in the short to medium term, as it is a mature and economic technology and can provide rapid benefits towards achieving the EU Kyoto's target*". The EU capacity for CHP is therefore targeted to double from 9% of EU power generation to 18%, by 2010 (European Commission, 2001b).

Some European Countries have experienced a rapid expansion in CHP capacity (Figure 2.3), largely brought about by favourable national policies and the deregulation of energy markets. The future expansion of the CHP market in Europe is therefore likely to be concentrated on the development of decentralised systems, based upon small CHP systems using gas turbine technology. This is partly because new policy initiatives are tending towards smaller and more localised CHP installations in buildings.

Small scale CHP is therefore well located as a strategic technology, important in addressing the tripartite energy concerns, as well as being firmly placed to meet the localised needs of SMEs in their consideration of sustainable business development. In the UK, the situation is very different, as there is no statutory requirement for a municipal or regional energy plan. All of these research reports do therefore need to be translated in workable policies for encouraging the use of CHP locally. Market forces and the relative position of each country in the wider economic cycle would already have dictated many of these policy initiatives. There is scope for implementing these policies within the context of meeting the UK Government's domestic CO_2 targets by 2010. Governments endeavour to develop an appropriate policy framework, businesses and Local Authorities generally have the task of operating within them.

Chapter 3
Environmental decision-making in Small and Medium Enterprises

3.1 Introduction

The role of the environment as a constraint on economic growth was given prominence by Thomas Malthus, in his essay on population, first published in 1798 (Hodge, 1995). In it, he noted the need for businesses to be aware of their environmental consequences of economic growth. Climate change and the increased use of electricity have further highlighted the need for environmental awareness, being consequences of the activities of humans (Section 1.1). In a survey of its members on the perceived effects of the Government's proposed climate change programme on businesses by The Institute of Directors, businesses were worried about the effect the CO_2 targets would have on UK competitiveness (Institute of Directors, 1998). The survey concluded that only 7% of the respondents thought the UK should introduce policy measures to meet its Kyoto targets before other Countries have done the same.

The survey therefore confirmed that businesses in general and SMEs in particular, oppose more sustainable production methods, because they believe that it results in higher production costs and lower profits (Rocky Mountain Institute, 1997). The climate change programme was subsequently introduced in the UK in 2001. It reflected a number of policy initiatives such as voluntary agreements for the reduction of energy use, Integrated Pollution Prevention Control, the Climate Change Levy and the business rates reduction scheme.

These policy initiatives are part of the realisation that strategic alternatives that offer financial benefits to achieve CO_2 reductions, do suggest a way forward in encouraging businesses to improve sustainable production or utilise processes that incorporate sound environmental practices. The use of sustainable production technologies therefore creates profit opportunities for businesses and in turn a supportive economic interest group. Government policy initiatives and tax incentives (Section 2.7) do not appear to be sufficient for encouraging the use of CHP. CHP policy makers have therefore called for a decision support framework for businesses to be used as an internal tool for middle managers in businesses in order to carry out an initial appraisal before a consultant is appointed to carry out a detailed study or design (COGEN, 1997).

Before any decision support framework is developed, there is a need for a closer examination of the internal decision-making process of SMEs, with respect to the introduction of environmental technologies and CHP schemes. A new policy framework may have to be developed in order to enable improved targeting of the communication process towards achieving the aim of increasing the use of CHP in SMEs, where appropriate. This Chapter is therefore intended to explore the decision-making process, so as to identify the basis for assisting the decision maker's approach to assessing the use of environmental technologies, such as CHP.

3.2 Decision Theory for Small & Medium Enterprises

Johnson, R., Newell, W. & Vergin, R. (1972:21), define decisions as making a choice from among a set of alternative courses of actions. Jabes, J. (1978:86-102), refers to decisions as a goal directed behaviour, made in response to a need, with the intention of satisfying a motive. Decisions in SMEs are generally made by managers or in some cases owner-managers. There has always been a general acceptance that one of the primary purposes of managers is to look towards the future. This implies that making decisions is based on an assessment of uncertainties. The decision-making process therefore starts with problem identification and ends with a choice. This process normally occurs within a framework of the organisation's development and growth priorities. Undoubtedly one of a manager's main tasks is to make decisions, but management is a multi-faceted job in which stewardship and control dominate. The decision-making process is therefore not without its constraints.

In many cases, decisions are made for future events and so involve a level of prediction of occurrences over time. The sequence of time is therefore a very important element in any decision-making process for SMEs and hence the general use of shorter payback periods than larger firms. Longer-term investment decisions, such as the consideration of installing a CHP plant, are crucial to the long-term success and growth of a SME. This is not only because of the level of financial investment required but also because such investments tend to necessitate a change in the operational characteristics of the organisation, consequently improving its productivity.

As CHP systems typically maintain their operational efficiency for about twenty years, a decision to invest in the technology may reflect the need to avoid future environmental regulations. In practice, capital-intensive investment decisions generally consider short-term costs against long-term gains.

Decision makers cannot know the future with certainty. Therefore, decisions to invest in an expensive plant such as CHP would involve an element of risk. The process that identifies and quantifies this risk, would involve an analysis of the organisation's particular requirements. This would imply that ultimately, for any such change in a business requiring a substantial financial investment, it is best initiated from within. Such a decision would also depend on the organisational mechanisms that are in place, so as to meet profit, organisational, technical and environmental challenges.

Therefore to move an SME from a level of low investment in clean technology to a higher investment level would require a change in its internal economic framework. The underlying principles of transaction cost economics then become very relevant to the understanding of how environmental imperatives can be given a higher profile in the decision-making process. Transaction cost economics in SMEs effectively dictates the decision of whether to use external consultants for implementing change or to develop in house capabilities.

It is the economic considerations within the decision process that dictate the decision or choice for each business (Williamson, O. 1986). Transaction Cost Economics is based on three aspects:

- Bounded Rationality;
- Opportunism;
- Asset Specificity.

The concept of bounded rationality infers the limit of rational capacity of individuals. It suggests that parties to a transaction will seek out and attempt to implement opportunities to improve efficiencies. In so doing, they are limited by their cognitive abilities (Williamson, O., 1986:173-174). It also refers to the management of change as the use of rationality that is bounded by the individual's unconscious skills, habits and reflexes (McGrew, A. & Wilson, M., 1982:112).

Opportunism relates to the potential consideration or profit that a transaction might offer and takes into cognisance the time dimension of any decision. Asset specificity is the term used to relate the transaction to a specific asset, as all such decision processes for the installation of capital assets are specific to the asset. In most cases, because of bounded rationality, an awareness of the economic benefits of environmental improvements, requiring a large amount of capital or a high level of technical expertise, is frequently lacking in SMEs. The suggestion therefore, is that for most environmental improvements, that are not core to a business, external consultants will be used to prime the decision process and in many cases external funding will be secured.

The difficulty of externalising environmental issues, however, is the risk of losing responsibility and control. In the case of expensive equipment such as CHP, this implies that the returns need to be extremely high, for it to be accepted by the SME manager. The commitment theory suggests that such a high risk is likely to be more acceptable to the manager if he/she maintains an element of control in the decision process and has a better understanding of the benefits that any change may offer (Joule, R. & Beauvois, J., 1998).

Other similar research has suggested that, when capabilities are obtained externally, companies also need to explicitly invest in their tacit content transfer. In such a scenario it is best that they should already possess some related knowledge within the firm to allow for the easier transfer of additional knowledge (McGrew, A. and Wilson, M., 1982:112). The interplay between the cases for externalising or internalising costs becomes more evident with an appreciation of the role of a champion and the effect of the economics of the transaction costs. Petts, J., Herd, A. & O'Heocha, M., (1998:728-729), in their study of the environmental responsiveness of individuals and organisational learning in SMEs, had also concluded that the key to the performance of all companies was an individual who was seen as a champion, not only for environmental policy but also for its implementation.

3.3 The Decision-making process in Small and Medium Enterprises

As well as the personal attributes and resources of individuals, external influences, i.e. social, economic and political all contribute to the decision-making process in small businesses (Bridge, S., O'Neill, K. & Cromie, S., 1998:63). The considerable importance of the individual's role in the decision process and the organisation's sustainable learning structures for the uptake of new clean technology cannot therefore be overstated. The lead time for developing a CHP scheme – usually about 2 years- and the limited availability of technical consultants would make it highly improbable that enough industry managers could be trained in order to achieve the Government's CHP target.

The use of CHP in an organisation may also require new skills and monitoring procedures. Staff training and changing job requirements may lead to constraints on time and management difficulties that were hitherto not there. Such a potentially complex arrangement of staff implications, training requirements and investment finance, would suggest a need for a new management framework. This new framework could be in the form of a Decision Support System, which allows for the externalisation of aspects of the decision-making components in a new, wider governance system, designed to improve the overall environmental management in businesses. This new governance system should encourage a hybrid between 'profit optimisation' and 'social responsibility' in evaluating the physical benefits to the business. It may also offer an opportunity to assume parallel benefits via ceteris paribus assumptions (a notion commonly associated with the work of economists).

Gold, B. et al., (1975:142) notes "*The benefit of such a system is that it would identify the major categories of benefits, burdens and risks associated with every element of the decision–making process and allow a derivation of their respective magnitudes using specific research data. By obtaining or aggregating the combined yield of these magnitudes, it is possible to arrive at a conclusion on the viability of a project*". In Section 3.2 it was suggested that the process of decision-making infers selecting from among a set of alternatives and is about making a choice. Choices are often made within a background of existing knowledge, personal intuition and relevant external information that also have to offer some cognition. In other words, it depends on the knowledge and understanding of the decision maker, to interpret the information available.

The process of decision-making is markedly different between large and small firms (Roberts, P., 1995:94). Larger firms have a more structured approach to decision making within specified rules and guidelines. Often this is referred to as 'rational' decision-making (Gallagher, C. & Watson, H., 1985: 174) relying on mathematical concepts for its implementation. Simon, H. (1957:2) notes that no process is entirely "devoid of the decision maker's bias" implying that no decision is entirely rational. Nonetheless, within SMEs, decision-making is greatly influenced and directed by Government legislation and operates within a framework of meeting short-term profits and cash flow criteria. Decision-making in SMEs is not therefore an entirely structured or 'rational' occurrence it is largely a function of the business climate, corporate culture, a perception of the firm's energy efficiency and the manager's personalities (DeCanio, 1993).

In SMEs, when information is imperfect or complex business decisions are involved, individuals may lack the ability for efficient decision-making and some may be induced to act opportunistically. As a result, substantial transaction costs occur and the market mechanism fails to be an efficient method of organising transactions (Moschandreas, M., 1994:70).

Decision-making in organisations is usually stratified into three levels - short, medium and long term, each having a different approach. These levels relate to the expected returns from the investment and the organisational structure. Heller, F., Drenth, P., Koopman, P. & Rus, V. (1981:35), explain that short, medium and long-term decisions not only differ in the time dimension but they have different functions within businesses. They argue that top-level leadership in SMEs is more concerned with the management of external relationships, including environmental issues, while middle management is more concerned with internal decision problems. The three levels would in turn involve:

- Higher Level -Those involving the replacement of capacity withdrawals.
- Medium Level-Those involving additions to available capacities.
- Lower Level-Those involving the displacement of functioning facilities.

Decision-making about CHP installation would fall within a higher-level span and within the remit of top-level leadership. There would be a consideration of economic viability, technical competence and statutory regulations. The SME would introduce a new technology when the manager's personal perception of the majority of these variables is positive. The factors that would determine its uniqueness are costs, outputs and the organisation's financing culture.

3.4 Strategic Barriers to the use of Combined Heat & Power in the UK

Academic studies to determine the barriers to the introduction of new technologies to businesses, and the environmental impacts of technical change, have agreed on the significance of three broad themes: economics, management of change and Government policies. A key factor noted by Kohn, L. (1995:64), when investigating the barriers to the use of Orimulsion as a new fuel in the E.U., was that economic models primarily drove technical changes in industry. Christie et al. (1995:238) suggested that *while greater knowledge is worthwhile in its own right, barriers to the adoption of new technology do not lie primarily in the lack of information or understanding*. More important mediating factors are the framing of problems within a social and political context, personal and institutional constraints (Owens, S., 2000: 1141-1148).

Policy making in modern Governments is therefore increasingly being recognised as the product of complex interactions between participants in policy sub-systems (Isnor, R., 1996: 46). The research by Kohn (1995), which analysed the convergence between environmental and economic systems, also concluded that the general lack of political commitment was largely responsible for the low investment of industries in environmental technology.

Studies on the adoption of cleaner technologies by SMEs have highlighted some key factors constraining the implementation of environmental technology (ECOTEC, 1983: ECOTEC, 1985). These are:

(1) Political and economic issues: Legal requirements; relevance to core business; risk to core business; general economic situation.

(2) Technology-transfer issues: access to information; confidence; independence; resource capabilities; costs; training.

A strategic review of the development of cleaner technologies also concluded that legislation plays an important part in the development of environmental markets and the stimulation of innovation (ECOTEC, 1992). There are some other notable drivers for environmental improvements in SMEs, including corporate awareness, financial incentives and institutional change. Public communication and project dissemination strategies have also been cited as having limited effect on SMEs (Bridge, O'Neill, & Cromie, 1998). A common theme in all of these studies is that Government policies, with regard to economic instruments and national electricity markets, are inadvertently creating significant barriers to the development of environmental technologies in industry. Hackett, S. (1998:271), suggests that this relates to the principle of path dependence, as a problem with the political and social feasibility of sustainable production, consumption policies and technologies. Within the scope of sustainable development, the challenge for the Government must therefore be to create a positive economic attraction to SMEs, for the installation of CHP.

The Government has sought to use economic instruments as tools for encouraging the use of CHP. This is part of a wider Government policy base with the following aims:

- Reduction of utility prices to all consumers
- Expanding competition among utilities
- Further deregulation of the utilities

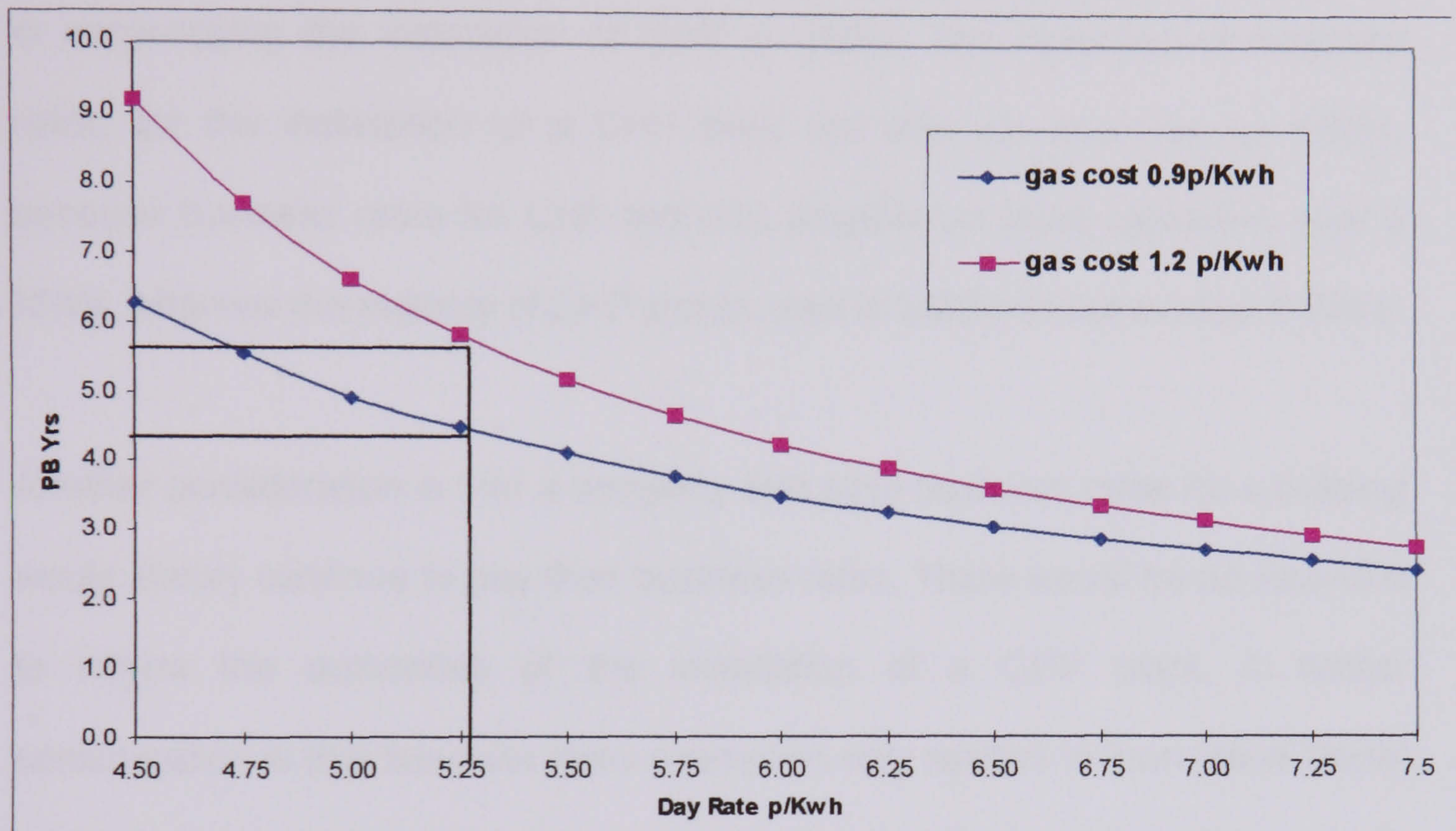
A general reduction of gas and electricity prices has steadily been achieved since the privatisation of British Gas in 1986. With the deregulation of the electricity and gas industries for the commercial sector in 1994, the commonly held expectation was for price reductions. In reality, based on 1992 levels, the decrease of 20% in electricity prices and 40% in gas prices by 1997, was substantially larger than had been expected in 1994 (Ofgem[23], 1997).

Another important factor in determining the economic case for CHP is the differential between gas and electricity prices, as they are the variable input and output parameters. In assessing the benefits of installing CHP, the significance of the relative fuel prices must not be overlooked, for these can have a major impact on return of capital. If the heat from the CHP substitutes the heat from the boiler with fuel at the same price, then the marginal effect on CHP profitability is related to the value of output electricity, as shown in Figure 3.1. It is a graph of CHP payback plotted against electricity unit charge at two gas price levels.

[23] Ofgem was partly constituted as Offer in 1997 which was set up as a regulator for the electricity market.

Figure 3.1 shows that at a particular electricity unit charge rate e.g. 5.25p/KWh, the payback differs by about 1 year, due to an increase of 0.3 p/KWh in the unit gas price. It also shows that the economics of a CHP scheme improves with a greater positive difference between electricity and gas prices.

Figure 3.1: The effect of utility price differentials on CHP profitability



Graph 1 - CHP Payback Vs Electricity Day Unit Rate & Gas Cost

Source: City of Westminster, (2001)

Between 1999 and 2002 there was a significant increase in price differential between electricity and gas unit costs for businesses (ILEX, 2003). As financial benefits from CHP investment is determined by the level of positive difference between electricity and gas prices, the economic case for CHP has therefore become less attractive since then, culminating in a reduction of available CHP capacity in 2002 (Section 1.2). The short-term paybacks have therefore not readily been available from CHP to SMEs in recent years.

Other Government policies generally expected to encourage the use of CHP by SMEs, have all proved to be ineffective in this regard. Enhanced Capital Allowances, which is a tax incentive for the installation of approved energy efficient equipment including CHP, does not offer any short-term cash benefits for SMEs, generally due to its high threshold and as such has proved ineffective in encouraging the installation of CHP in SMEs. The reduction of business rates, for the installation of a CHP does not offer an incentive for SMEs, because business rates for CHP are only payable on plant capacities over 1 MWe, whereas the majority of CHP plants used in SMEs do not exceed 1 MWe.

Another consideration is that a company that pays business rates for a building would simply continue to pay their business rates. There would be no incentive to inform the authorities of the installation of a CHP plant. A further consideration is that business rates exemption only applies to "non stand alone" plant i.e. plant not owned and operated by a third party. An estimated proportion of over 75%, of current as well as anticipated future CHP capacity are however owned and operated by third party contractors (ILEX, 2003). These policy instruments, well intentioned as they are, do not suggest any long-term economic rationale for the use of CHP by SMEs. They do have a particular significance however, as acceptance by the Government of a strong link between financial benefits to SMEs for the use of CHP. The challenge therefore is to identify new mechanisms, either in the way of a governance framework or other type of incentives that may attract SMEs to CHP.

3.5 The use of Decision Support Systems in Small & Medium Enterprises

Economists have long deliberated the profit maximisation motive of enterprises; especially Small and Medium Enterprises. Turner, K., Pearce, D. and Bateman, I., (1994: 250-251), argue that this prime motive for profit maximisation must not be seen as conflicting with an environmental improvement imperative. However, Betts, R. (1980:62), argues that the notion of profit maximisation, as a prime motive, is a limited understanding of the operation of small businesses within a highly competitive market. He suggests that managers take decisions not to necessarily maximise profits but to meet reasonable standards of performance in areas such as profits and market share. He refers to this concept as *'Satisfycing'*.

'Satisfycing' implies that decision-makers pursue sufficient satisfactory goals rather than some 'one best goal'. McGrew, A. & Wilson, M. (1982:62), suggests that a decision framework that offers a number of decision parameters, not all in financial terms, would also be based on a rational decision process and offering some benefit to the limited rationality of decision making in SMEs. This trend of thought should form the basis of a new support system[24] (DSS) for encouraging the increased use of CHP in SMEs. Any proposed decision support system should be based on a broad set of parameters that should not all be quantified in financial terms.

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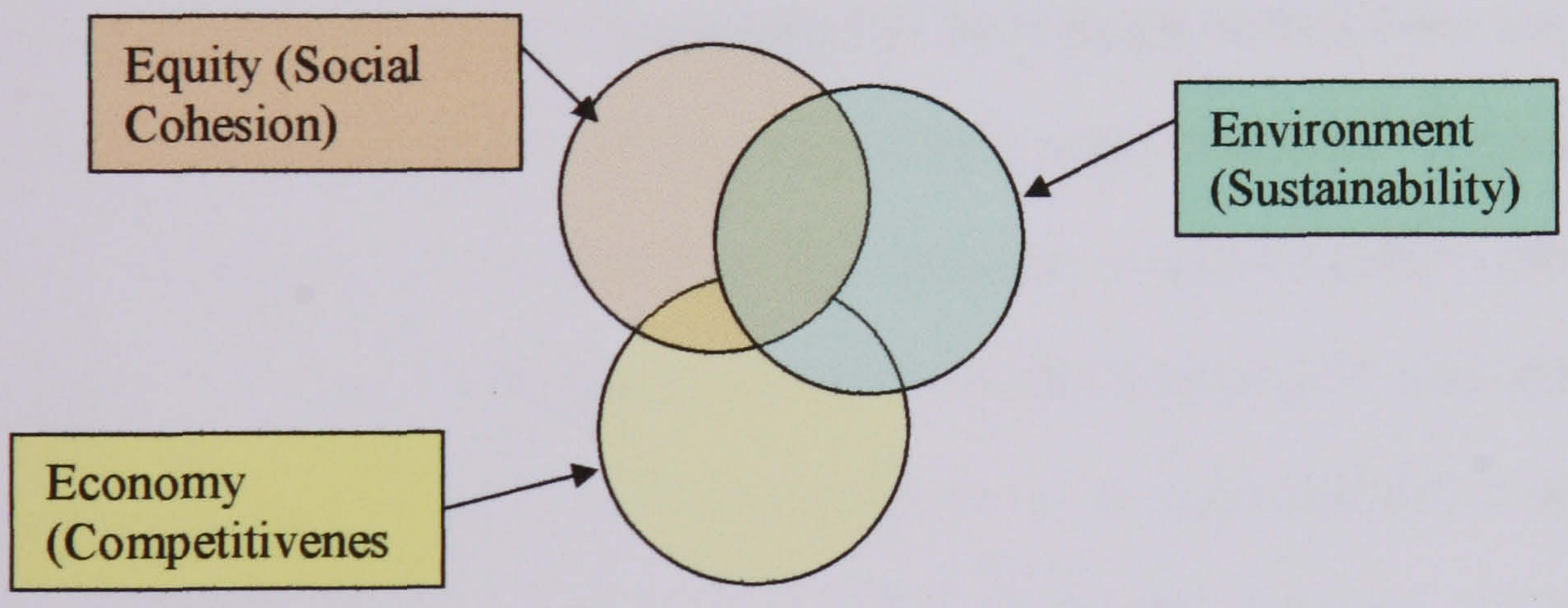
[24] Decision support systems couple the intellectual resources of individuals with the capabilities of computers to improve the quality of decisions. It is a computer-based support for management decision makers who deal with semi-structured problems (Kersten, G., Mikolajuk, Z., & Yeh, A., (1999)

In such a system, particular attention would need to be given to the internal mechanisms of the business and the way in which organisational factors influence the decision-making process. A simplified example of this system is depicted in Figure 3.2, proposed by the 'London Futures Group', (1998). The significance of this model is the section that is common to all three circles. This section indicates the interdependence between the Social, Environmental and Economic aspects of business performance. It lends credence to the argument for a decision framework that gives equal value to all three parameters as part of the decision process. In effect, the model suggests an increased realisation that improving technical efficiencies of production or reducing operational costs are not independent considerations for the adoption of clean technologies.

Figure 3.2: The E^3 Model of Sustainable Development

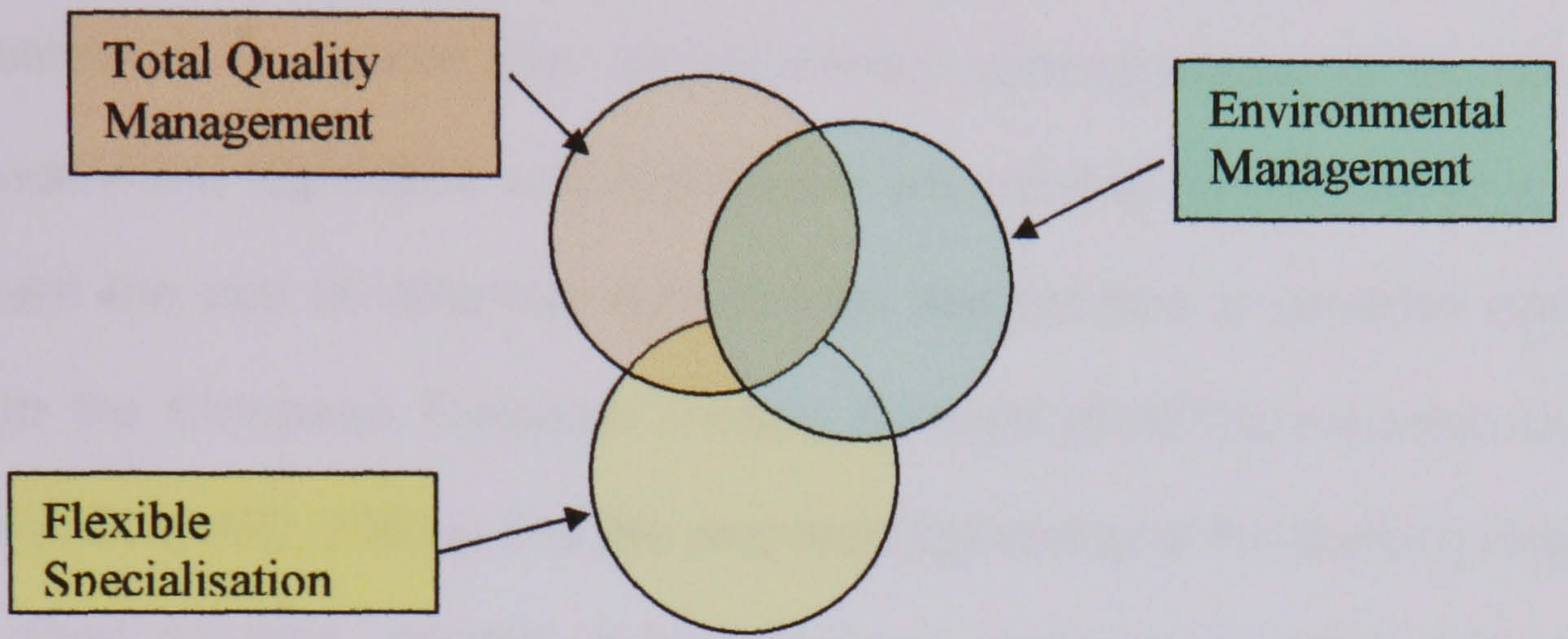


Source: The London Futures Group, 1998

It also demonstrates the value of a new decision-making process that recognises the internalisation of costs that have previously been treated as externalities. This would encourage a change in the 'nothing to do with us' mentality. Such a framework infers an integrated approach to decision making, in a way that enhances the business' role in its social environment.

Welford. R, & Gouldson. A., (1993:177) had already suggested a similar model (Figure 3.3) as *"an ideal model for the sustainable development of small and medium businesses".*

Figure 3.3: The "Ideal" model of Sustainable Development for businesses



Source: **Welford. R, & Gouldson. A., (1993)**

The model (Figure 3.3) integrates quality management, environmental management and flexible specialisation techniques noting them as the sort of objectives that might be set for a successful small business. It could therefore be considered as the basis of a new Decision Support System, which offers a framework for an integrated analysis of the benefits of CHP and may therefore be the way of achieving the twin objectives of an appraisal and a realisation of the benefits of CHP. There may also be further benefits, such as health improvements, that cannot be captured within the existing economic framework which evaluates only costs and benefits (Sarafidis, Y., Mirasgedis, E., Georgopoulou, E. & Lalas, P., 2002: 196). It is expected that a new framework should integrate the SMEs environmental, technical and financial performance.

3.6 Conclusion

The process of change in economic and business thinking that is implied by the concept of sustainable development is one that shifts the burden of responsibility from Government to the business. It is no longer acceptable for businesses to ignore the environmental consequences of its operations. Government legislation and regulations are moving businesses in a direction where the use of voluntary agreements has become a common occurrence. With the European Emission Trading Scheme (EUETS) expected to start in April 2005, (EC, 2001a) and the proposed tightening of the Building Regulations in 2005 (DEFRA, 2002b), It has become vital that environmental concerns become embedded in corporate business strategy. High transaction costs and bounded rationality were identified as limitations to CHP capacity building (Section 3.2). An argument could therefore be made for the development of a tool to assist in decision-making as part of the strategy for considering the environment as an implicit aspect of business strategy.

This tool or Decision Support System could be an opportunity for developing a new decision process within SMEs, for considering CHP or other clean technology schemes that offer economic benefits as well as a stimulus for improved environmental management. The sustainable development models in Section 3.5 provide a clear indication of interplay between three distinct factors (in each model) for developing a sustainable business strategy.

These performance factors could generally be regarded as falling within two spheres of influence, external and internal. However these two spheres are not mutually exclusive, as the external (Governance) decision framework ultimately informs and directs the company's (internal) decision system. The logic of the argument for a new decision framework is that by obtaining a "commitment" through empowering the individual at a level where the decision-making process is initiated, he/she would be more likely to enhance the consideration of CHP as at a time when its application may be necessary. This 'commitment theory' is based on the strategy of freely consented submission. Joule, R. & Beauvois, J. (1998), in developing this theory further note that "*rather than forcing or convincing, effective change is obtained by carrying out acts, that a priori, are insignificant (non committal), but that nonetheless lead the participant to think about the process and behave differently as a result*".

The new decision frameworks could be represented as Decision Support Systems, allowing for an examination and ranking of financial, social and environmental effects. These systems must have as drivers, proper communication and support strategies, inherent within them. This would enable SMEs to access adequate information in a form that they can readily understand and easily use. Economic viability, technical complexity, the effectiveness of the Government's communicating strategy, the level of technical know-how and sustainable learning within SMEs, are all key issues that would need to be moulded in to these support systems.

They would create a business scenario where the decision to install CHP is a regular option for consideration, in the decision-making process within the organisation. Within this process there should also be scope for training of the business' personnel for adapting to the use of the CHP technology.

The justification for a new Business Decision Support System for SMEs is therefore to encourage the use of CHP in SMEs, based on the need to change the way decision makers approach investment decisions. This change needs to be from a purely financially based assessment to an assessment that includes a consciousness about environmental responsibility and its costs. This is also the basis of the argument by Connelly, J. & Smith, G. (1999: 279), that a *"monetary valuation of environmental benefits should be included within existing decision-making processes, the financial returns priority that decision makers give over environmental factors needs to change to reflect environmental costs".*

Chapter 4 provides a further consideration of the potential use of Decision Support Systems based on the discussions in this Chapter. It then develops an empirical structure for use as an initial framework and a basis for analysing the data collected in this research process.

Chapter 4

Improving the energy framework for Small & Medium Enterprises

4.1 Introduction

The justification for this Thesis was taken from the need to reverse the decline in the build up of CHP capacity (Figure 1.1), in relation to the potential identified in Table 1.2 (Section 1.2). The basis of the argument for SMEs is that there is a greater capacity to install CHP than is currently realised. Whilst there is an increased tendency to offer SMEs a common identity, it is worth noting that their characteristics are very different and they are motivated by different parameters. Hillary (2000) suggests that the market sector, ownership and the location of an SME are key factors in the decision-making process that the organisation follows. The market sector influences the regulations, the skill base, and operational parameters of the organisation. The ownership determines the internal decision-making process, the level of risk acceptance and the organisational structure. The location of the organisation also influences its social interactions and its response to governance issues that are area based. Managers also have to consider internal regulations within the context of a national framework. This Chapter therefore develops the argument for a new policy framework and examines the possible structures it might take. From the literature review it conceptualises a new policy framework noting that SMEs decisions are influenced at two distinct levels;

- The Governance framework within which the organisation operates.
- The internal processes for the organisation to achieve its objectives.

4.2 Examining the current governance of national energy policies

Independent research commissioned by the EST (EST, 2000a), showed that a significant number of SMEs, are still unsure of where to go for energy efficiency advice. They are unaware of services provided at the local level or through Government schemes and are confused by the range or mix of services offered. In some business support organisations, there is also a lack of awareness of energy advice sources (LDA, 2003). Invariably energy efficiency is therefore not an issue that is generally linked to the achievement of financial targets in small businesses. Government programmes such as the Integrated Pollution & Prevention Control, have centred on the use of direct marketing strategies in encouraging energy efficiency in larger businesses, where it is anticipated that greater energy savings can be made.

The extent of energy efficiency advice provided by non-specialist organisations (Business Link, CHP Business Clubs etc.) to SMEs, is patchy in its coverage (both in terms of geographical extent and time scale), and variable in terms of what level of advice is offered. It is also not well coordinated as the DEFRA's Regional Energy Efficiency Officers and the Regional Carbon Trust Officers work to differing objectives and agendas. Mainstream business support providers (such as Business Link), are often unaware of where to go for detailed energy efficiency advice and CHP business clubs often deal with the issues as just part of a general environmental or business review package.

Table 4.1 is an outline of the existing pattern of energy advice/service provision in the UK (EST, 2001).

Table 4.1: Energy Efficiency Advisory Services in the UK for SMEs

AGENCY	NETWORK COVERAGE	SERVICES OFFERED
Carbon Trust -Action Energy	Service provided across English regions	Free advice and energy audits, including provision of a helpline and web site.
Government Energy Efficiency Office	Energy efficiency officer per English region, with the exception of Eastern.	Free advice and energy audits, limited provision of a help line. Level of activity varies between regions.
Energy Agencies	One per region, coverage within region varies	Provides low levels of SME service due to limited funding and staff.
Business Link Network	National coverage, number of individual Business Links varying per region.	Advice, workshops and provision of environmental reviews. No energy services. Services are charged, may be subsidised.
Groundwork	45 offices, only 25 providing energy efficiency advice. Links with local networks,	Advice, workshops and environmental audits. Central Energy and Information Centre for enquiries. Subsidised services.
Business club	Coverage varies by region	Environmental advice & Energy reviews.
	Source: EST, 2001	

In discussing the scope for a new energy policy framework for SMEs consideration has to be given to the governance of the framework. How is it to be established, promoted, monitored and communicated to SMEs? What type of approach is required to maximise benefits to SMEs and encourage network between actors? The Actor Network Theory suggests that for SMEs, both a sectored and a regional approach would be appropriate (Oakes, S., 2001). A sectored approach offers scope for like minded business networks that would focus on the intricacies of a particular business type. This approach has limitations for knowledge transfer across business types and encourages duplicity in knowledge bases.

A regional approach is suggested by the *d*CARB-uk[25] project, based on a scoping study by the Tyndall Centre for Climate Change Research (SDC, 2003). The scoping study concluded that;

- There is considerable activity in carbon reduction at local level some of which is driven by national policies and some developed locally.
- The potential for local to regional carbon reduction remains untapped.
- The regional development of sustainable energy has some success stories but these are few in number and limited in scope.
- Sustainable energy issues have largely been marginalised within much of local Government (with some notable exceptions)
- There no carbon reduction initiatives integrated across spatial scales
- Local and regional carbon reduction offers the potential for tackling multiple policy and social objectives.

These conclusions offer a basis for any proposed policy framework for CHP use in SMEs, to be set up as an identifiable governance framework in line with proposed Government priorities for regional governance. An area based approach also enforces the concepts of bio–regionalism and permaculture, which leads to a discussion of eco–sustainable planning policies (Section 2.4). In the particular case of CHP, a governance framework may be linked to service delivery specified within a statutory framework. Regional governance therefore offers the scope for integrating development policies, to achieve a coherent delivery of public services and the delivery of Sustainability Plans (DEFRA, 2002d).

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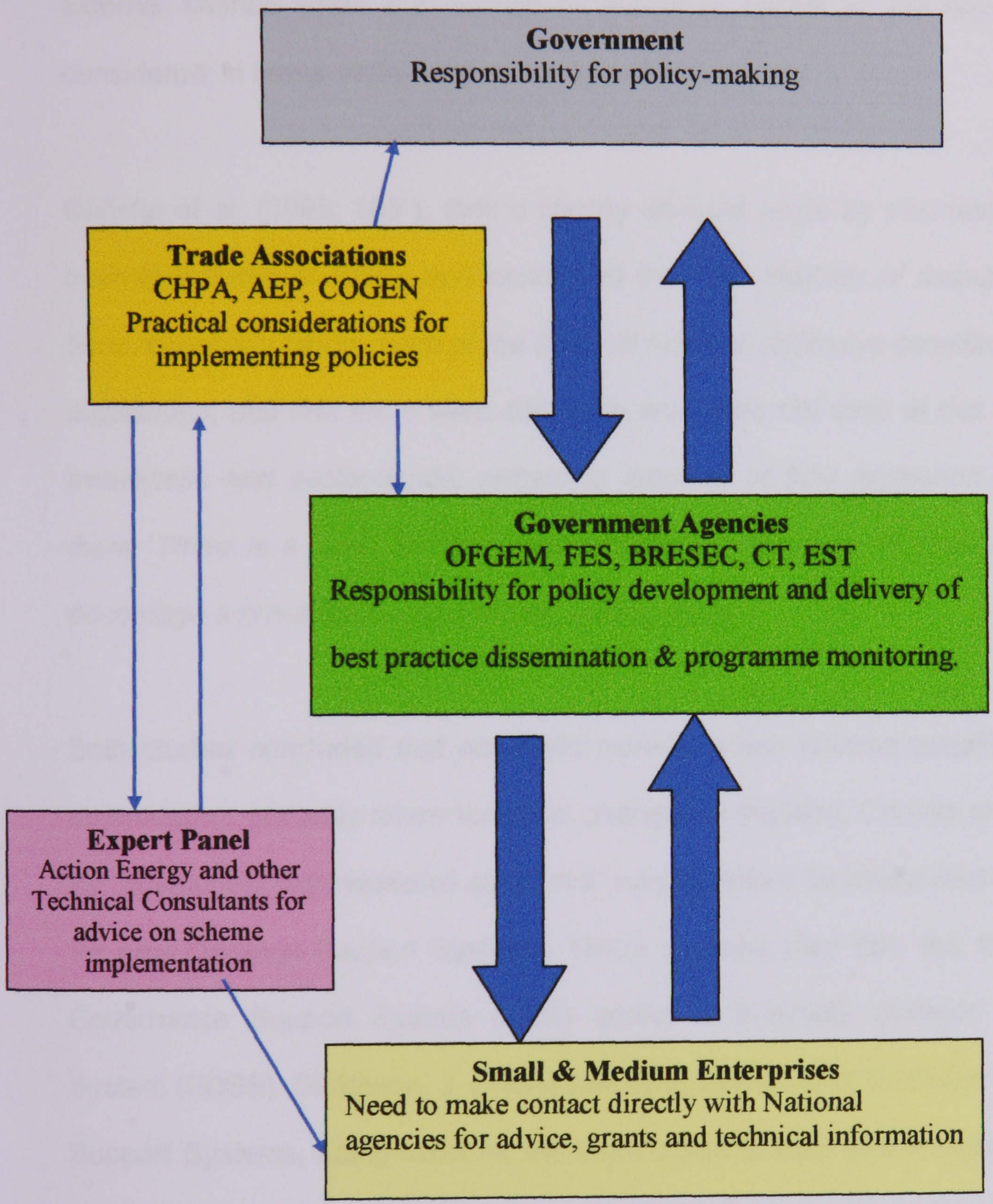
[25] Low Carbon Spaces: Area – based Carbon Emission Reduction: A report to the Sustainable Development Commission prepared by the Tyndall Centre for Climate Change Research

Such spatial energy policy frameworks are not new and are currently being actively promoted within the EU. Adams, G. (2001), former MEP for the North East of England, believes that "*without a regional context, the EU cannot deliver its European Energy targets*". A regional energy governance framework should include new elements or considerations that are not included in the current national energy governance framework shown in Figure 4.1.

This framework offers limited scope for communication between policy makers and beneficiaries and is a top –down framework model that require new elements to improve its efficiency. Some new elements to be addressed are:

- Regional financial support based on developing local resources.
- Operational expertise such as may be provided via an ESCO.
- Technical Barriers - such as connections and metering issues.
- Bounded Rationality - technical pool for ensuring CHP expertise.
- Communication strategy – local demonstrations and planning consents.

Figure 4.1: The Current Policy Support Framework for the governance of Combined Heat & Power use in Small & Medium Enterprises



Adopted from "Invitation to tender for the SMEEEAC Service", EST, 2001

4.4 Studies relating to the development of a conceptual framework

Mohd Amin, M., (1997: 26), in analysing national policy interactions and their effects on environmental improvements in SMEs, emphasised the importance of external finance when the context of economic benefit to the business is considered; in terms of the cost and availability of finance.

Christie et al. (1995: 163`), took a slightly different angle by emphasising the internal cultures of SMEs and concluded that "*the majority of manufacturing firms, especially SMEs, were at the stage of minimal, defensive compliance with regulations, and that there were still many who were not even at this stage of awareness and performance, remaining ignorant of how legislation affected them. There is a need for the development of organisational structures that encourage a pro-active environmental management*".

Both studies concluded that economic models, which showed benefits to the organisation, primarily drove technical changes in industry. Christie et al's call for "developing organisational structures" may therefore be interpreted as a call for new Decision Support Systems. These systems may take the form of a Governance Support System (GSS) and/or a Business Decision Support System (BDSS). Dickinson, J. (1991) also cites examples of Business Decision Support Systems, being used for the introduction of new technologies. These were based on systems methodologies and the principles of BATNEEC[26].

[26] BATNEEC is defined as the 'best available technology not entailing excessive costs (Hutchinson & Hutchinson, 1996: 197).

In acknowledging these principles, the academic studies are then used as a basis for designing the research for developing the framework of a new GSS. They note that any change in governance should be closely linked to the effective use of economic instruments as policy instruments, to encourage change in SME. The studies also indicate the need to allow the development of knowledge bases or decision support systems within this supporting frame.

The design of this research was therefore based around the following themes as a way of meeting its objectives.

1. The effects of economic instruments, designed to encourage the use of CHP.
2. The impact of the organisation's structure in the decision-making process.
3. The technological constraints to the use of CHP.
4. Availability of funding to support the use of the technology.

For future projects the new support systems should provide signposts for:

- What type of information is most useful to SMEs?
- What format is the information required to be in?
- What additional services are available to supplement the information?
- Where examples of these projects are found locally?

4.5 Conceptualising a new policy framework for using Combined Heat & Power Systems in Small & Medium Enterprises

In addressing the need for a new and integrated policy framework for improving environmental management in businesses, due consideration should be given to the interrelationships that should exist within the new policy framework. The use of an inflexible framework would be however be fraught with much difficulty, as it, in a sense, suggests homogeneity for SMEs, and does not acknowledge the vast differences between SMEs. In Sections 3.2 and 3.5 there was a discussion on the decision-frame for SMEs and the link between social, economic, and environmental issues. Those parameters would therefore determine the future framework for policy models in order to encourage improved environmental management by SMEs.

Such a link can be expressed in the form of three decision models or support systems, each representing a unit of the E^3 model showed in Section 3.5. The social dimension of the decision-making process, does not normally offer much variation, as it is a reflection of the location or region of the organisation. It is therefore possible to imitate the decision-making processes in two distinct framework strata, within which decisions are to be taken. The first relates to the national policy framework and the other to the specific organisational responses to internal developmental initiatives.

As this Thesis is set within the context of SME use of the CHP technology, it is considered appropriate to utilise a scientific approach to the analysis of the management decision-making process (management science), by the development of computer aided decision support systems. The most important point of this approach is to support managerial decision making by improving the quality of the information made available to the organisation's managers. Gheorghe, A. (1999) notes "*the need for systematic processes to be followed that help structural thinking and analysis and allow for different viewpoints to be taken into consideration. Structuring helps avoid inappropriate ad hoc decisions and allows the process of reaching a decision to be more open and the decision itself to be more readily defensible. In the end the use of various decision aiding techniques and the overall process and technology of decision analysis allows the integration of various risks at regional and area level*".

Using computer based analytical techniques also allow for a combination of quantitative analyses and qualitative assessments within a single decision support system (Anderson, D., Sweeney, D., Williams, T. 1985:4). A similar approach was adopted by Kersten, et al., (1999:2-3) in the determination of sustainable development models for businesses, suggesting a "*modern management approach, offering guiding principles for effective policy making*" in Box 4.1. These principles offer a basis for interaction between the external governance regime of national regulations and internal organisational requirements.

Box 4.1: Guiding principles for effective sustainable development policies

- Make a holistic sustainable development approach to the decision-making part of mainstream thinking.
- Establish a framework to use sustainable development in any project justification and rationale
- Consider sustainable development as a business problem a combination of economic, technical and environmental solutions.
- Finding a solution that allows a consensus between these three parameters should be the optimal goal.
- Decisions should be made with the use of Information Technology.
- Any project resulting from this decision support system should be treated as one that requires evaluation, support and proper planning.

Source: (Kersten, et al., 1999)

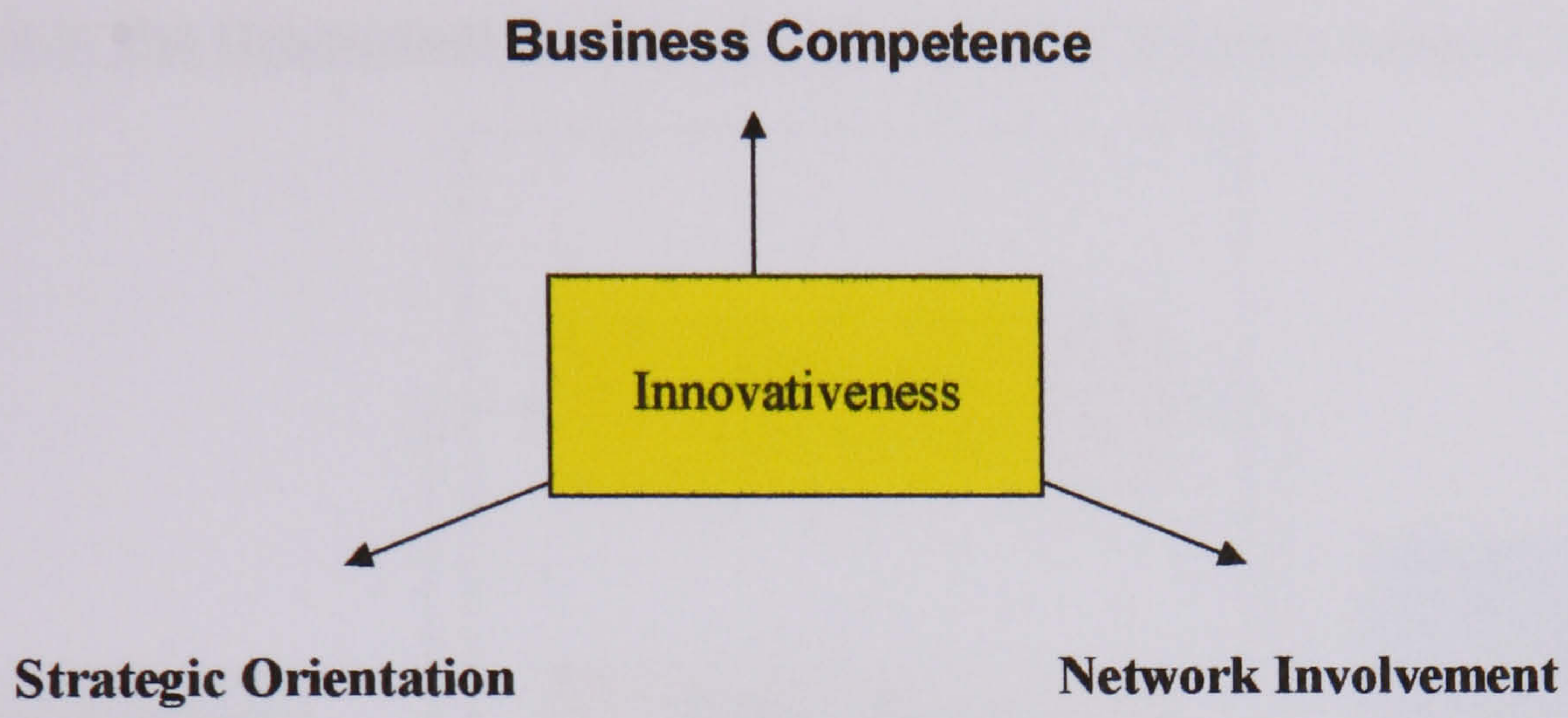
In the determination that Government policy is the most important driver for innovation and investment in SMEs, Rothwell, R. & Zegveld, W. (1982b), offered a simple model for the realisation of the innovative capacity in SMEs, which sets out the criteria for developing the innovative capacity within SMEs:

- Information about technical feasibility.
- Information about the demand.
- Investment funds (or information about attracting investment).

These criteria refer to the internal decision making culture of the organisation and are determined by the extent of bounded rationality within the organisation. In a sense, they are symbiotic in their relationship and determine the unique nature of the decision- making process within the organisation.

Van Dijken, K., Frey, M., Hansen, O., Lopes, E., Meredith, S. and Kalff, P. (1998), also presents these criteria and their interdependence as a simple model (Figure 4.2), and note a cross reliance to form a triangular effect.

Figure 4.2: The Network of Competence and Capabilities in Businesses



Source: Van Dijken et al. (1998)

Welford, R., (1993) had also envisaged such a model as the basis for integrating the various sustainable development criteria into a decision support system. His proposal was based on the national Geographical Information System[27], which included facilities to:

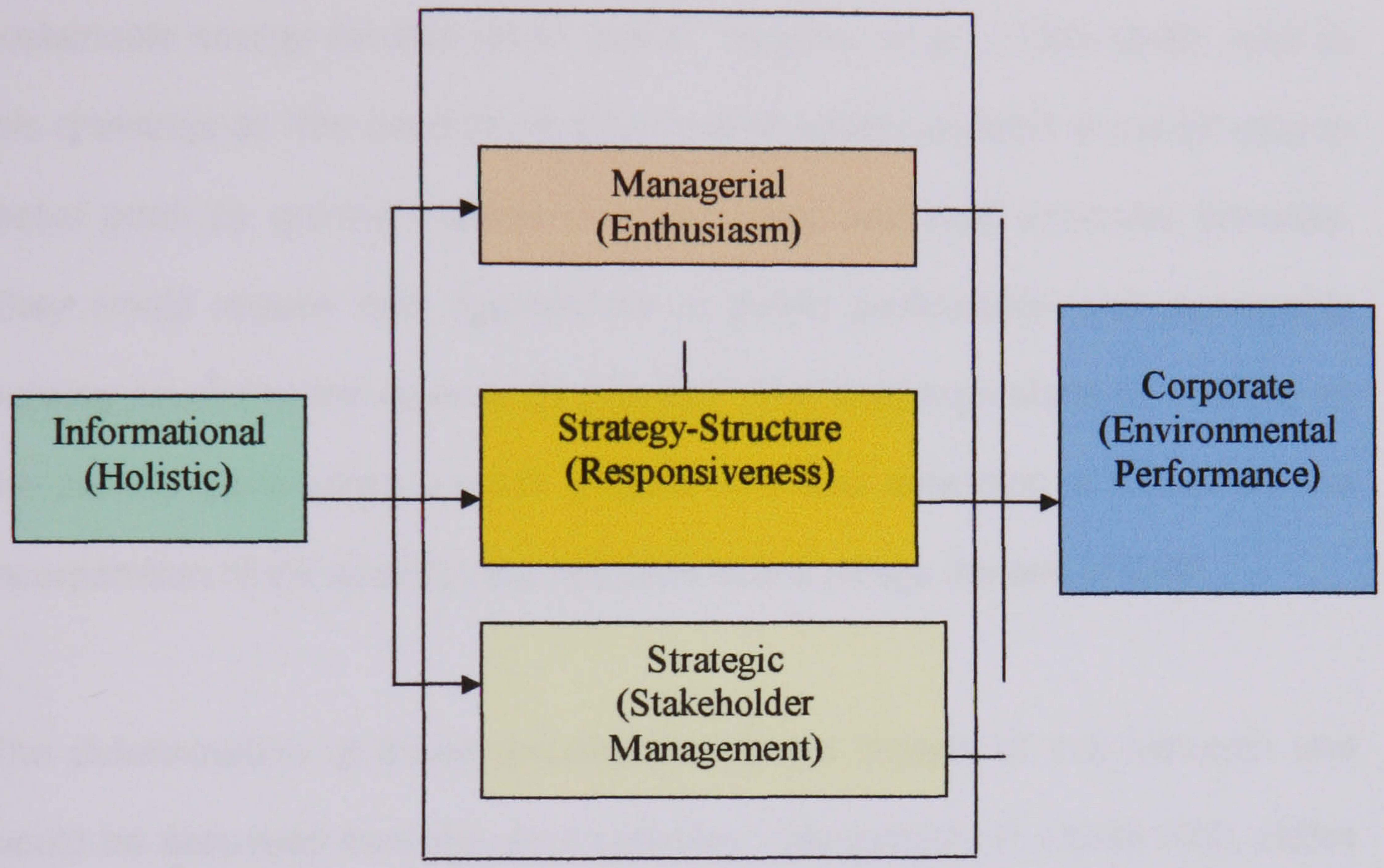
- Monitor infrastructure developments
- Foster communication between industry and local communities
- Develop local models and environmental targets
- Identify opportunities for new investment and growth

This gathering together of the environmental and regional imperatives was conceptualised in Figure. 4.3 in a *"new Governance model"* (Lang, J. (1995:29).

[27] The National Geographic Information System is a grid based mapping system that offers geographical information of various locations across the UK.

Lang referred to Figure 4.3 as "*an important tool, required to integrate the demands of environmentalism into strategic sustainable development planning which shows output indicators that relate to the overall objective of the organisation*".

Figure 4.3: The Conceptual Environmentalism Model (Source*: Lang, J., 1995)*



These output indicators are stated in terms to which an SME can relate and in decision units that reflect time frames for decision-making. They also identify information as the most important input, which in turn emphasises the importance of an adequate communication strategy. Hillary (2000:189) suggests that widespread and untargeted information campaigns are likely to have only very limited impacts in SMEs noting that a governance framework managed on a regional basis therefore offers a better opportunity for a coherent and targeted communication strategy, better suited to SMEs.

This was the logic for the Energy Saving Trust setting up the pilot SMEEEAC network by on a regional basis (EST, 2001b), a structure which later proved to be ineffective as a mechanism for reducing CO_2 by SMEs. It epitomised a new challenge to the thinking of Government in delivering its environmental and social objectives, one that would probably incorporate a new concept of regional sustainable energy centres (EST, 2003). Burgess, et al., (1998:1449), refer to this challenge as "*the need to develop local strategies capable of contributing to global goals by gaining support from the public and local economic interests. They would require new approaches to public participation and partnership building as part of the Agenda 21 process*". The challenge starts by building on the current governance system (Figure 4.1) and extending it further by the incorporation of the specific requirements to encourage the use of CHP.

The determination of these requirements is the subject of this research and would be assessed from the data collected. Glasbergen, P. (1998:705), states that a good place to start, would be from the standpoint that "the new governance system would have to provide the impetus for a learning process or series of activities that develops to a field of involved parties, at both the micro (Enterprise) level and the macro (area based) level". This would imply that any new governance system should be based around a theme of localising the decision framework, on the basis envisaged by the European Union's principle of 'Subsidiarity[28].

4 The European Union's principle of 'subsidiarity' states that action should be taken at the lowest effective level of Governance. This term gained prominence in European Political debate in the 1990's after the Maastricht Treaty (Burgess, J., Harrison, C. & Filius, P., 1998).

For any proposed Governance Support System (GSS) to achieve its stated potential, it is important that it does not require too fundamental a change in Government legislation, as this would severely hamper the chances of its acceptance. Therefore, any proposed system should build on the existing framework model for the governance in the UK, including the proposed development of the EEACs into Sustainable Energy Centres (SECs) in the UK. The challenge would then be to develop a new integrated governance model for CHP that would reflect the triple factors of social, economic & environmental, such as in the E^3 model (Figure 3.2). The structure of this research should enable key business environmental performance indicators to be derived for use in the GSS, with which both SMEs and policy makers would feel comfortable. These indicators would offer a practical enhancement to the current Governance of CHP in the UK.

The proposed GSS should be capable of fitting into existing Regional or Local Authority structures that already carry out a number of carbon reduction programmes as noted in Section 1.3. Within these types of initiatives, Devolved Assemblies and Regional Development Agencies have the scope and finance to assist in the regeneration of businesses in their areas as evidenced in the East Midlands area (Fleming et al, 2002). Using Figure 4.1 as a starting point for the proposed governance system, a concept of the new Governance Support System, should lead to improved corporate performance in a way that recognises the capabilities noted in Figure 4.3.

Of particular note is that the framework envisages the SME having a direct relationship with Development Agencies in terms of grants, inputs into development programmes etc, but that all commissioned works would be directed via an expert panel such as the proposed Sustainable Energy Centres. A representation of the conceptualised GSS is therefore shown in Figure 4.4, as a framework that sets out the parameters within which a SME's decision-making process may be carried out. It is also intended as a co-ordinating structure within an area for energy management.

Table 4.2 Justification for a new governance structure for CHP in the UK

Problems identified in literature review	Solutions offered by new structure
Inadequate Communication channels	Closer local marketing potential
Financial assistance, grants, networking	Integrated grant assistance programmes
Integrated Planning and Building Control	Dominant control and planning authority
Bounded Rationality, no Internalisation	Scope for central knowledge base

Table 4.2 offers a justification for suggesting the adoption of this change to the existing governance framework for the use of CHP in the UK. The significant difference between Figure 4.1 and Figure 4.4 is the introduction of a central role for area based management in governing the delivery of Government policies. Government agencies are afforded a less important role, without a primary responsibility of policy co-ordination across regions.

Figure 4.4: Concept of the Proposed Governance Support System

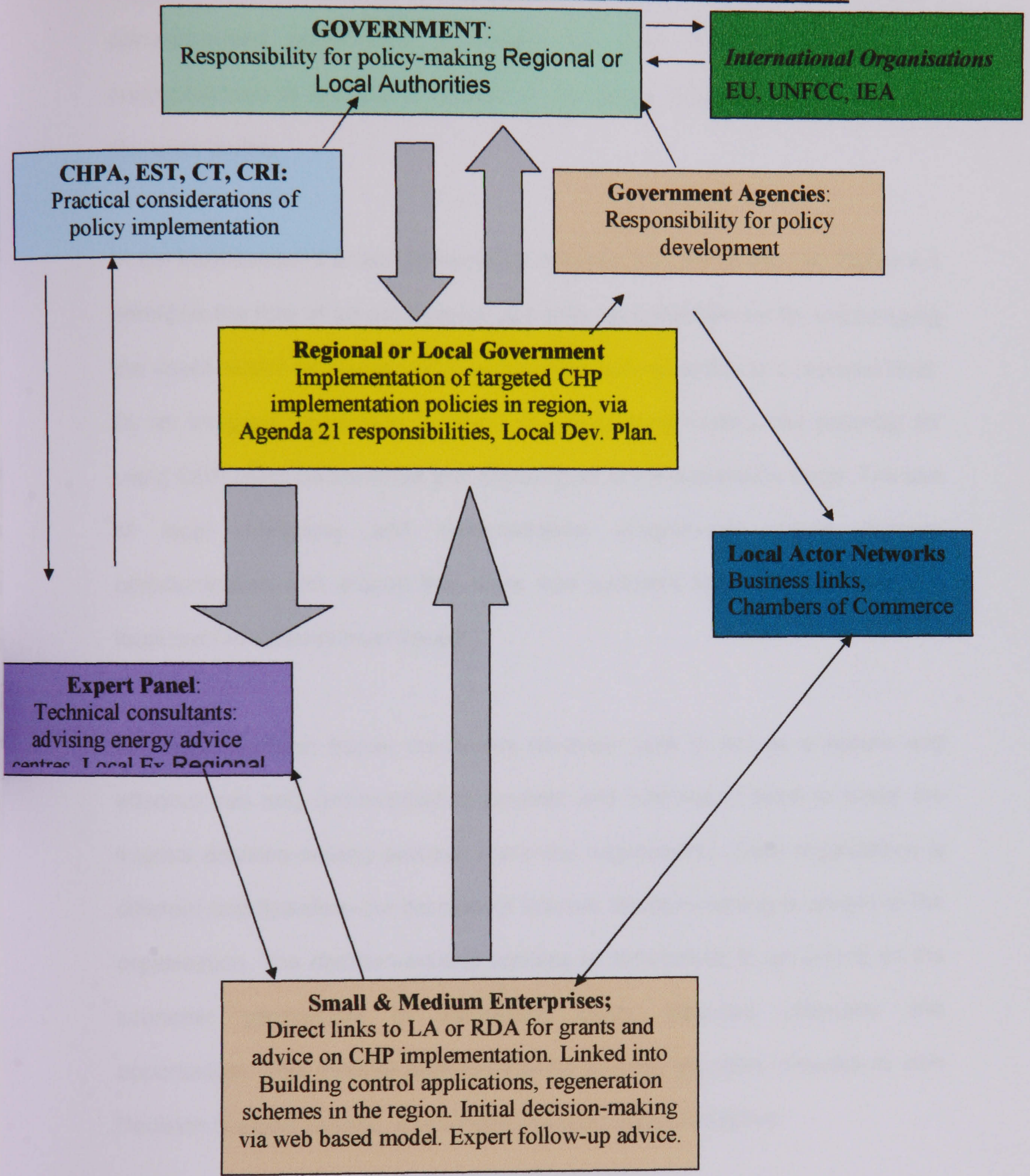


Figure 4.4 therefore includes spatial management as a "new" factor in the conceptualised governance framework for CHP. This new factor was conceptualised to address a number of the issues that were identified in the literature review.

In the justification of a new governance structure for CHP in the UK, Figure 4.4 identifies the role of an area based Authority as a mechanism for encouraging the devolvement of responsibility and targets from a central to a regional level. By an integrated approach to planning and building control, the potential for using CHP could be identified and encouraged at the application stage. The use of local marketing and demonstration programmes would improve communication and ensure that there was sufficient technical expertise at a local level to address local issues.

Any such decision frame, could only however seek to act as a secure and effective two way communication channel and information base to assist the internal decision-making process within the organisation. Each organisation is different and therefore the process of internal decision-making is unique to the organisation. The decision-making process is determined, to an extent, on the economic perspective of transaction costs, bounded rationality and opportunism. This internal decision-making process therefore requires its own Decision Support System, a Business Decision Support System.

4.6 Existing Business Decision Support Systems for Combined Heat & Power

In the research of the effects of Transaction Cost Economics on SMEs, Boira-Segarra, I. (1996), concluded, "*when capabilities are obtained externally, companies need to explicitly invest in their tacit content transfer and should already possess some related knowledge within the firm for the external advice to be useful and acted upon*". Useful comparisons could also be made with the research finding by the EST, (2002), when examining the likelihood of actions following advice to domestic households. The conclusions were:

- Customer led advice is usually more effective than opportunistic advice;
- Effective advice mechanisms are verbal; face to face; interactive;
- Take up of grants is lowest among those who receive only written advice.

Although the EST research was carried out on domestic households, it is clear that in SMEs, the decision process normally involves a few individuals. A comparative assessment study on the scope for integration of decision support systems for energy policy management noted a number of decision support models and associated software tools which provide energy performance indicators for business investment decision making (Gheorghe, A. 1999). Antoniou, Y. and Capros, P. (1999) also note the development of the PRIMES energy model as a decision support framework of the European Commission to support the seamless integration of data management, model running and reporting. Such individual studies are relevant to the operation of SMEs as they represent a computer based approach to decision making within financial and technical constraints.

The reality however is that SMEs frequently have limited internal capabilities, incentives and funding for CHP scheme appraisals. There is a strong case for a new policy initiative, which assists decision-making in the SME and encourages internalisation (Section 3.4). In order to establish the structure for a new Business Decision Support System (BDSS), it is prudent to examine a few CHP appraisal models currently used as for SMEs by technical consultants. These existing Decision Support Systems are limited in their consideration of the technical and financial aspects of a CHP project appraisal as they are designed primarily to assist in the determination of a financial viability for the use of CHP within a site. They share a common conceptual framework shown in Figure 4.5. It is derived from the DTI (1994) Energy Demand Model (Figure 4.5a) for the services sector, which considers the criteria for an efficient client service delivery.

Figure 4.5 then follows to show that the considerations in the models are essentially technical including electricity interface demand profiles, hot water or steam. There are however, specific differences in the outputs of the appraisal models and, as such, their use is determined by the parameter that the client is most interested in measuring. Examples of three BDSS' in use are compared in Table 4.3, noting the positive & negative attributes of each model;

- The CHP Financial Analysis (Thames Energy Ltd[29], 1995)
- The Good Practice Guide, CHP Appraisal Model (DEFRA, 1999h)
- The Action Energy (previously EEBPP) "CHP Sizer" (DTI, 2000c)

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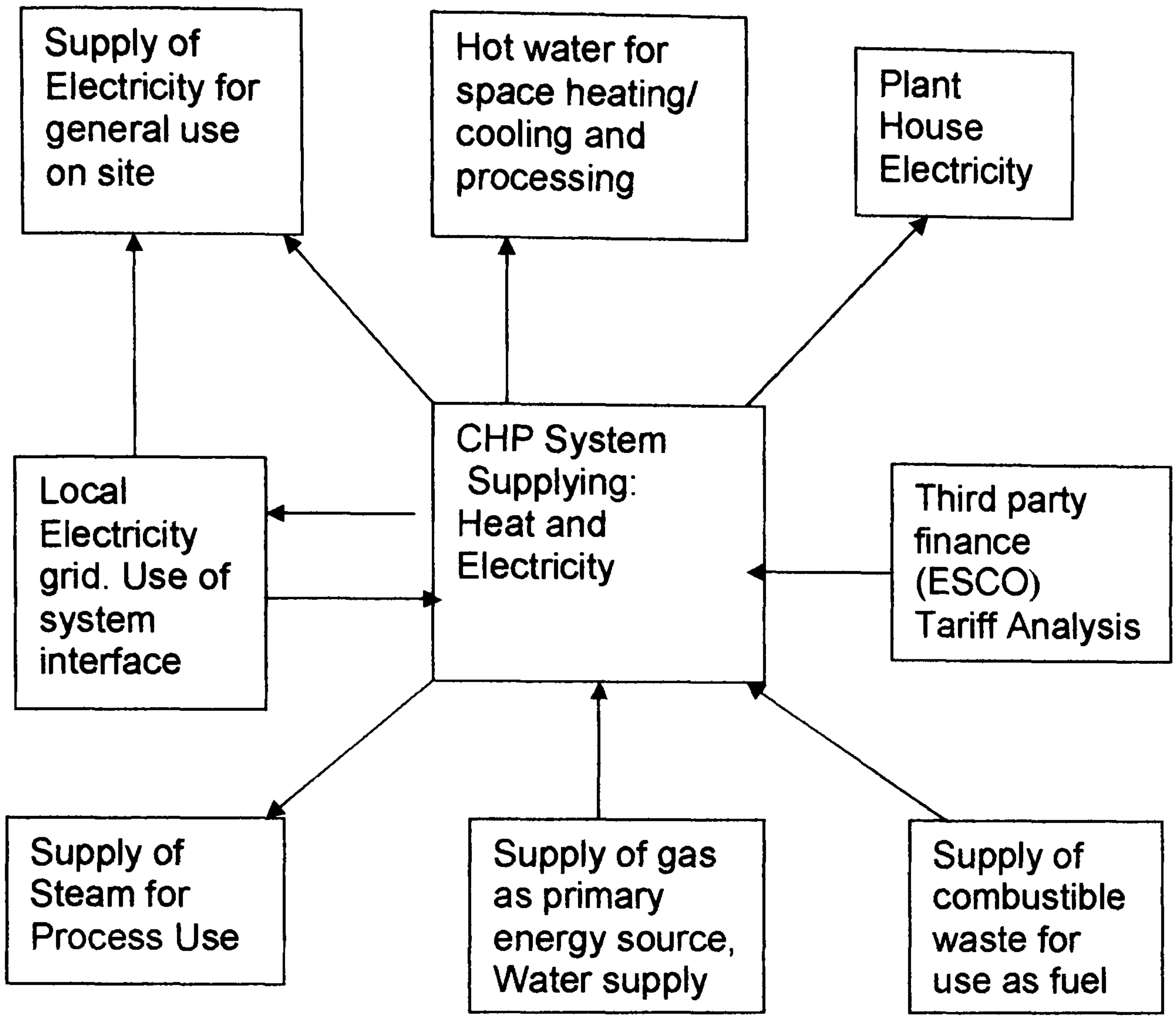
[29] Thames Energy Ltd was Waltham Forest Energy Services Ltd prior to April 2003.

Figure 4.5: Technical inputs for a Business Decision Support System



Source: Combined Heat & Power Association, 2000

Table 4.3 Comparative analysis of CHP decision support models

Model	**Advantages**	**Disadvantages**
Thames Energy Ltd CHP Financial Analysis	Simple to use, finance led approach for determination of viability	General assumptions about existing plant performance. No consideration of environmental benefits
DEFRA Good Practice Guide	Includes environmental considerations. Also has good explanatory booklet	Very technically oriented not user-friendly to the non-technical manager.
Action Energy CHP "Sizer" model	Financial, technical and environmental analysis. Provides environmental quality index.	Developed for use in domestic CHP analysis. No integration of indices for decision making.

4.7 Conceptualising a new Business Decision Support System

A requirement for developing a new BDSS is that it should combine the key output indicators into a single index to be used as a benchmark or performance indicator. It should also offer easy comparison between schemes with differing output parameters. Such a new integrated model would identify the technical, financial and environmental benefits of a CHP decision as a single output indicator. This would be in addition to the consideration of the operational implications of any CHP decision. CIBSE (2002) also advocates such an approach, noting, *"the financial and environmental benefits of CHP should be simple to assess for small scale users (<5mWe), not the current mess of potential benefits that we are being offered by consultants".*

In the conceptualisation of the new BDSS, a useful starting point is the framework for use by technical consultants[30], as recommended by the CHPA (2000). This framework, (Figure 4.6), indicates the complexity of the input requirements and the decision process for the consultant. For the manager, these considerations are somewhat premature if the project proves to be either too expensive or does not meet the benchmark environmental criteria. A new model that requires limited inputs e.g. site fuel utilisation in order to determine an optimal plant size based on a combination of financial, environmental and technical criteria would be a simple way of determining the viability of a scheme.

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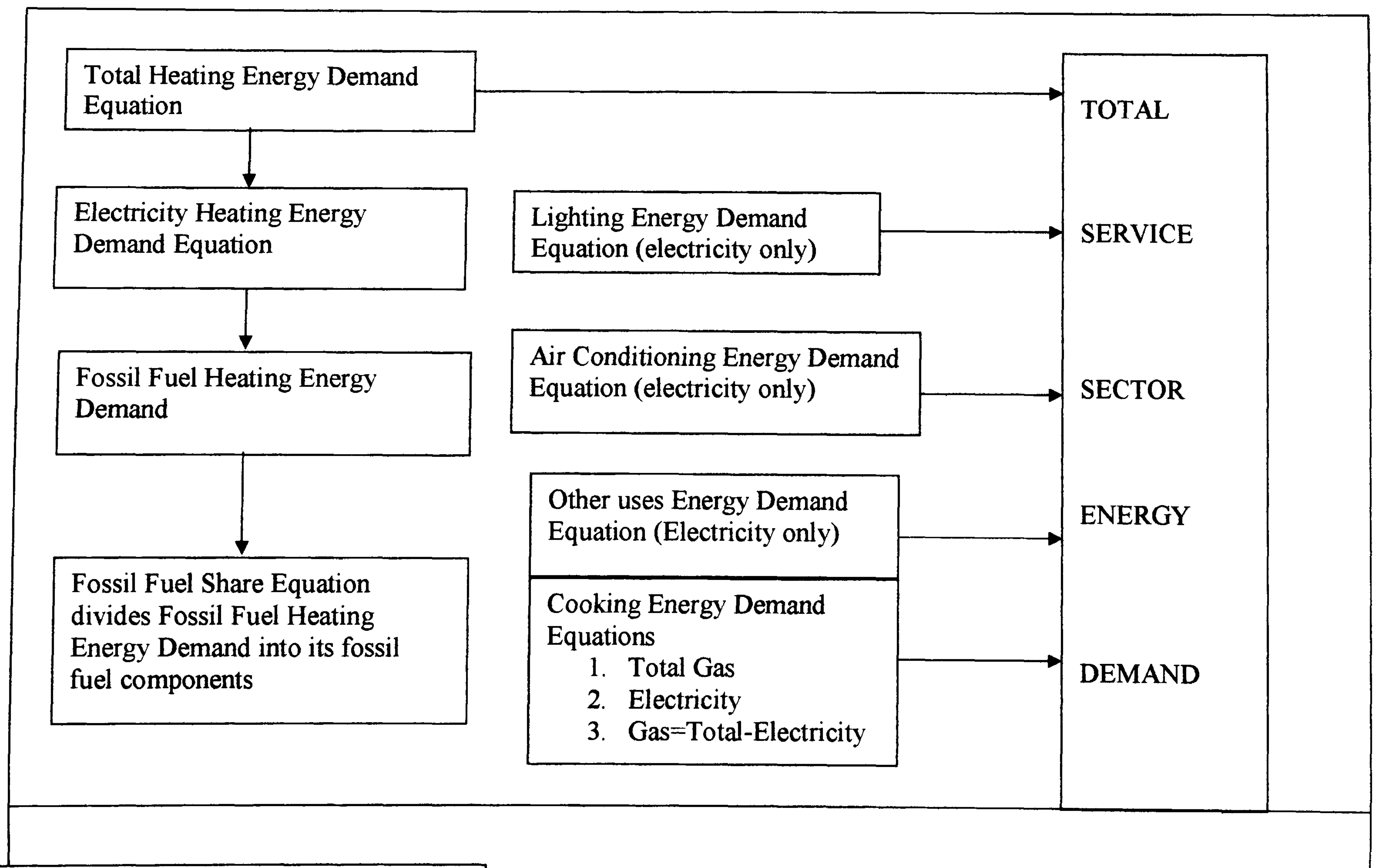
[30] A technical consultant in this capacity is one that is a qualified chartered engineer who has at least years post qualification experience in the field of Energy Management. Accreditation by the Carbon Trust as an 'Action Energy Consultant' is also frequently cited as an example of a consulting engineer.

By using data obtained in this research, other engineering parameters can be factored into the model as indices and used in conjunction with the limited data inputs, to develop a flexible working model within an existing GSS framework.

Gold, B. et al., (1996) suggest a similar framework for a BDSS, shown in Figure 4.7, as the pattern of a technical decision-making process, for a major technological innovation in SMEs. In this, they suggest a relationship between external and internal factors in the decision-making process. In the case of the proposed BDSS, the external input is to be provided by the information base of the GSS. By an adaptation of Figure 4.7, to allow for the parameters noted in Section 4.4, a new framework for a CHP decision support model for SMEs could be conceptualised as Figure 4.8 to include primary energy, waste minimisation, and existing plant technical parameters.

In order to establish whether the relationship between the input parameters for the decision-index of the project is of a modular value, it is essential to define the unit of measurement of each input parameter. In this way, it then becomes feasible to move from a static decision framework to a dynamic framework. Any change in the input requirements, would be consistently applied to all other parameters in the model, thereby ensuring the integrity of the model. Figure 4.9 shows the units of measurement of the input parameters that are identified in Figure 4.8. Figure 4.9 therefore ensures that all measuring criteria for the model are defined in advance and would lend themselves to easy input by potential users.

Figure 4.5a THE DTI SERVICES SECTOR ENERGY DEMAND MODEL



Source: DTI, 1994

Figure 4.6: Key Consultancy Activities for a Combined Heat & Power Project Feasibility Study, Source: CHPA, 2000

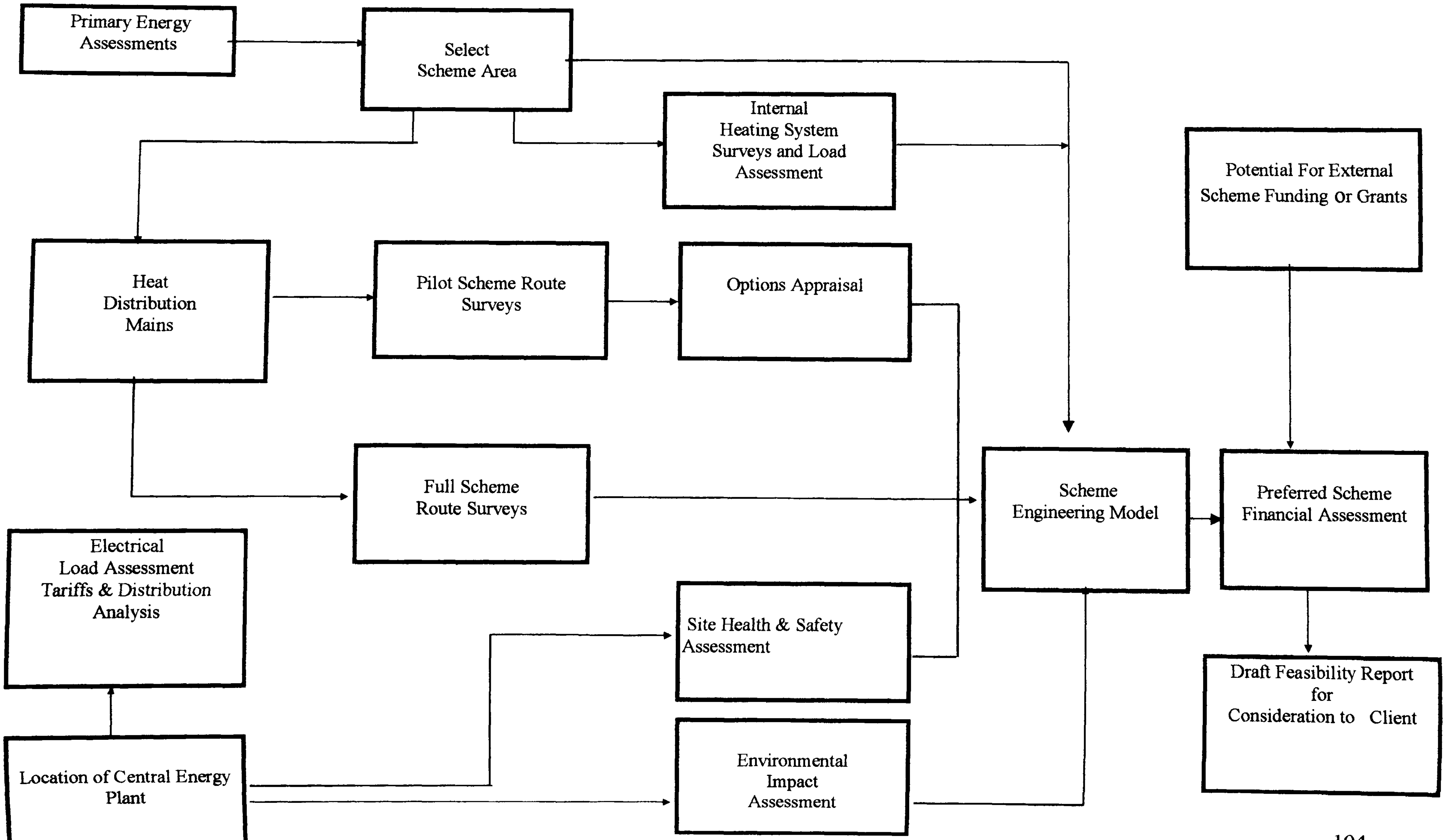


Figure 4.7: The Decision Making Process for Major Technological Innovation (Gold, B et al. (1995: 140)

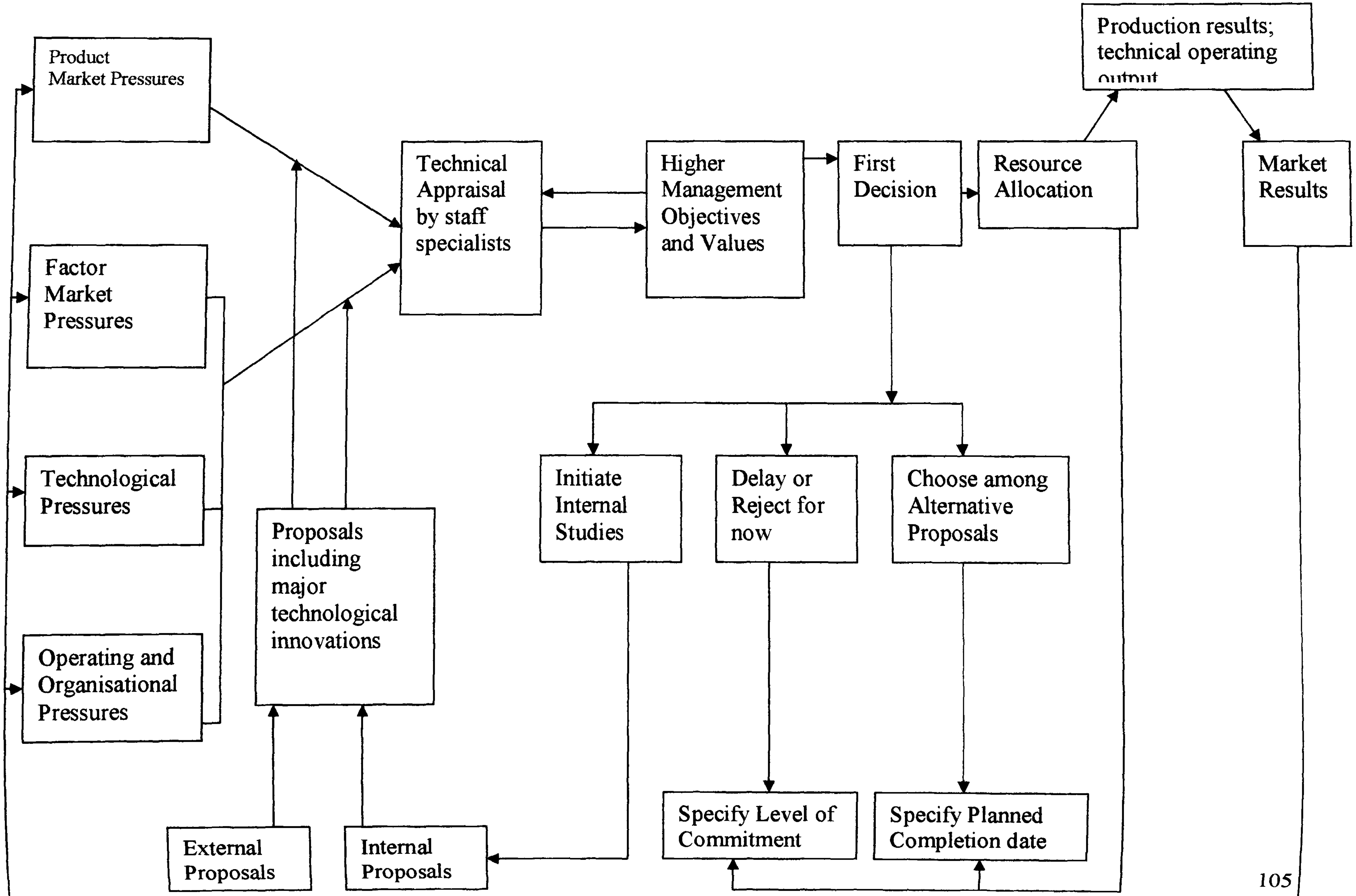


Figure 4.8: An Adaptation from "Framework of Decision-Making Process for the Adoption of a Major Technical Installation"

Source: Gold, B. et al. (1995)

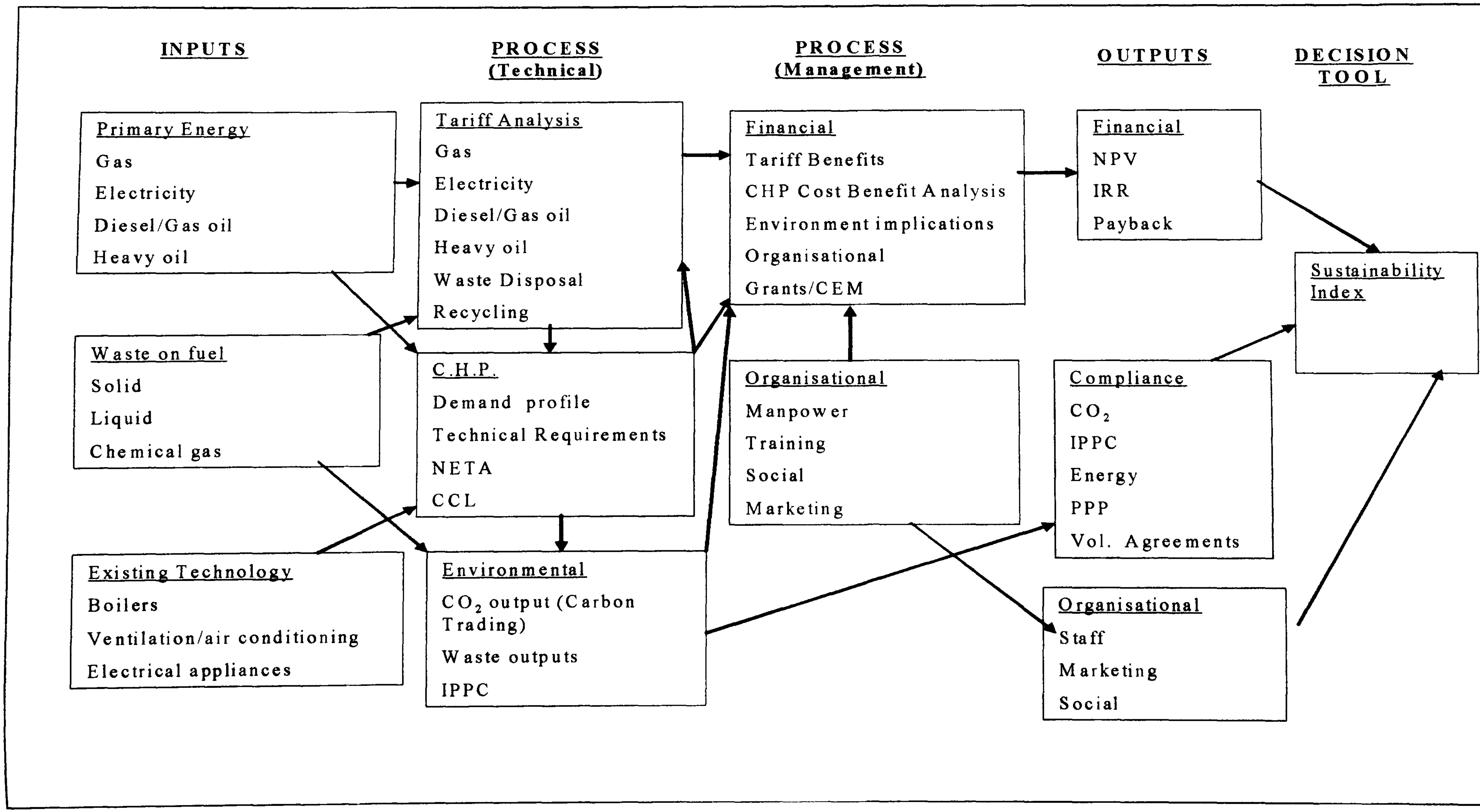
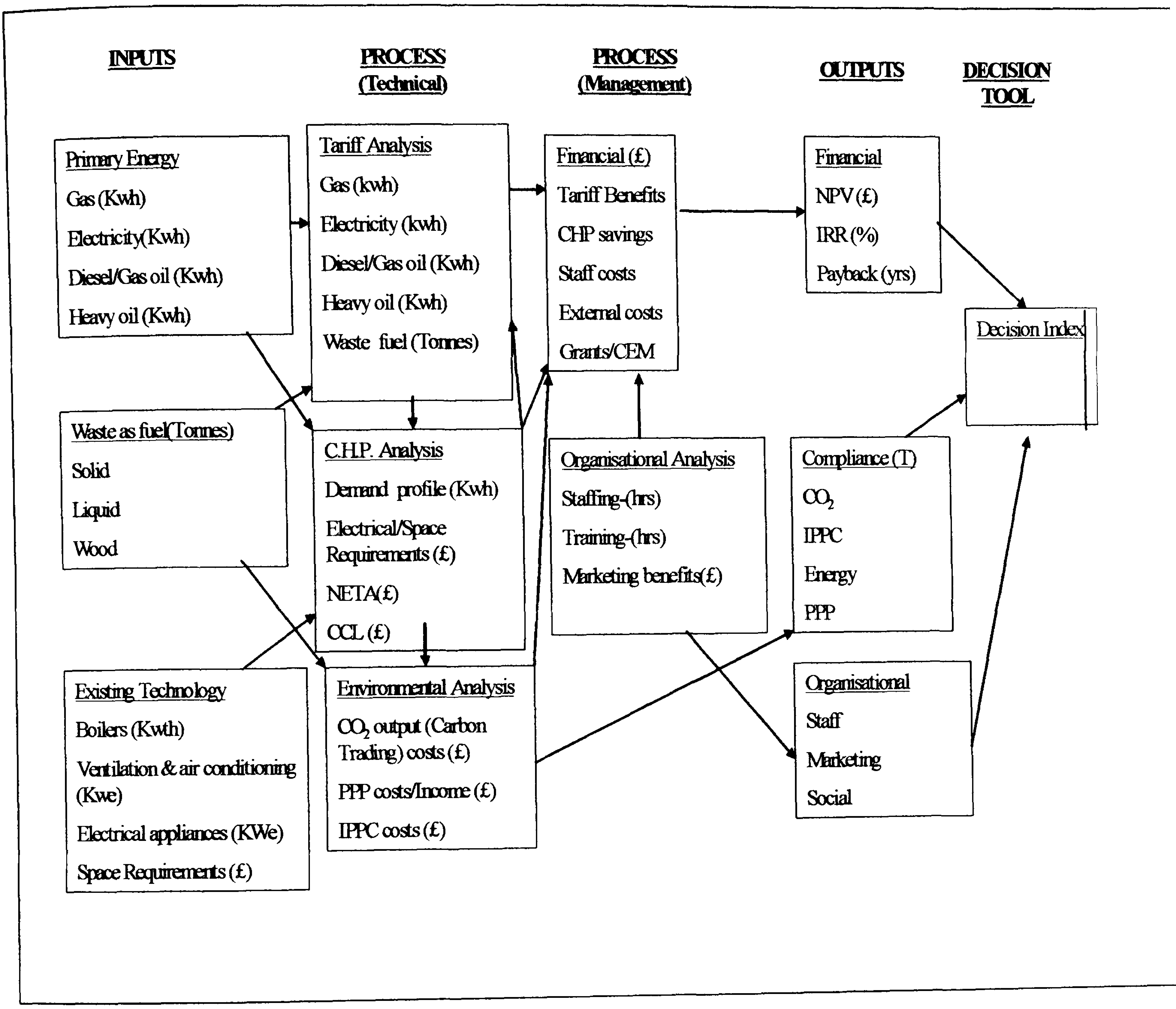


Figure 4.9: A conceptual model of a Business Decision Support System



4.8 Conclusion

An improved communication channel and the provision of easy access to a concerted pool of local/technical data would be the difference between the conceptualised CHP governance system and the current. This is suggesting a fundamental change in approach to the way CHP is being governed, by shifting the information base from a centralised approach to a area based approach. The proposed support systems infer that a useful strategy to change the way businesses approach environmental management, is to change the current network strategy. The recognition that the parameters in the E^3 and Ideal sustainable business models (Figures 3.2 & 3.3, Section 3. 5) fall into two distinct levels that influence decision-making by an SME, offers an opportunity to develop two different, but complimentary support systems. In a sense, these support systems relate to the longer and medium time spans of decision-making. The GSS incorporates an authority and responsibility for policy issues on a spatial basis and is in line with the important role of 'Subsidiarity' (Section 4.5) in the drive to increase the use of CHP in SMEs.

The structure of the BDSS seeks to bring together the environmental, financial, technical and organisational inputs to the decision, in a single model. It allows for a consideration of bounded rationality, opportunism and "asset specifity" in addressing the economic viability of any proposed CHP transaction. The use of a Decision Support Index as a guide to viability ensures that the responsibility of the decision-making still remains with the manager. In addition, the use of the index for benchmarking also offers useful comparisons in the decision-making process.

Chapter 5

Research Design and Data Collection

5.1 Introduction

A key factor in the design of any research study is to ensure that the data collected provides evidence to address the research objectives. The research design in this study is therefore dictated by the structure of the enquiries to be carried out and the methodology to be used in the process. Section 1.7 had earlier identified the research objectives and noted the aim of the research. In the determination of the methodology for this research, consideration was given to issues that relate to various perspectives such as positivist, critical rationalist, interpretive and grounded theory. The methodology for this research was eventually based on critical theory as it identifies more closely with the theoretical perspective of the study objectives, the way in which results are to be analysed and conclusions derived.

This research used four methods for data collection and ultimately, the analytical techniques used were related to the data collection method. The four data collection methods used in the research were structured such that they were iterative in their approach, which allowed for the results of one method to inform the design of the next stage of the research process as shown in Figure 5.1 (reproduced from Section 1.8). As such the methods produced results that could be validated in their own right and allow for meaningful conclusions to be reached.

Figure 5.1: A Diagrammatic Representation of the Research Design

	JUSTIFICATION	METHODS/ PROCESSES
PHASE 1	• Literature review • Define aims and objectives	**Strategy**: Case Study **Purpose**: Determination of common factors in data sets **Method**: Desk-top exercise
PHASE 2	• Conceptualising a new policy Framework for CHP • Evaluating characteristics of SMEs that are conducive to CHP	**Strategy**: Analysis of National CHP database. **Purpose**: Evaluation of key characteristics of SMEs using CHP **Method**: Desk-top Computer based statistical analysis
PHASE 3	• Interview with policy makers • Surveys of existing CHP operators • Development of the Decision Support Systems	**Strategy:** Assessing the policy framework for CHP **Purpose:** Exploratory/Evaluation of previous data **Method:** Semi-structured Interview, Survey questionnaire
PHASE 4	Developing the new policy Framework for CHP use in SMEs • Arguing the justification for a new policy framework • Recommendations from the research	**Strategy**: Analysis of Results **Purpose**: Determine of policy effects and inputs for DSS' **Method**: Computer based data analyses

Source: Adapted from Young, C. & Welford, R. (1998)

5.2 Developing the methodological perspective of the research

The ontological perspective of this research is the mitigation of greenhouse gas production, as a means of minimising the negative effects of climate change as discussed in Section 1.1. Any research to address this issue, must therefore address the means by which the efficient use of fossil fuels could be achieved. The 'Greenhouse Effect' is a natural phenomenon based on scientific interfaces of chemical and atmospheric considerations. It could therefore be easily concluded that any study of this phenomenon should be based on a positivist methodology. In this case, quantitative methods would be used to determine the effect and extent of the benefits derived from the introduction of clean energy technologies such as CHP.

There are however, various brands of positivism, Blaikie, N. (1995), identifies twelve. Much care is therefore needed to properly define an appropriate type of positivist methodology that could be used. The most relevant brand of positivism is logical positivism, which is based on the laws of natural science and refers to the uniqueness of experience as the only reliable basis for scientific knowledge (Blakie, N., 1995). Bryman, A. and Burgess, R., (1994:14), further explains that logical positivism entails a belief that only those phenomena which are observable, i.e. facts can validly be warranted as knowledge. This in effect rules any subjective assessments or feelings, which are prevalent in social science research.

Popper, K. (1961) criticises and distances himself from logical positivism as an unreal science, and offers the alternative notion of critical rationalism. Critical rationalism, shares a similar ontology with positivism. It, however, rejects the logical positivist position in favour of a critical method of trial and error commonly known as the method of hypothesis (Blakie, N., 1995). It is tempting to adopt a critical rationalist approach to this research, as comparisons could be made with other European countries such as Sweden, Denmark, and Finland where national policies have been successful in the introduction of energy efficient technologies. The hypothesis then to be tested would be the examination of the potential for replication of these national policies, in the UK. To do so would however be to ignore the care required in avoiding the risk of neglecting the cultural and social constructions of the research process (Silverman, D., 1997).

An Interpretivist approach in contrast, would lead to a much greater understanding of the meaning and context of the behaviour of managers in industry and the processes that take place within observed patterns of interrelated factors. Interpretivism, however, fails to acknowledge the role of institutional structures particularly divisions of interest and relations of power. An interpretive methodology would therefore limit the extent of understanding of the issues and would provide information relating to individual assessments rather than institutional responses. As this research is directed at considerations of management structures that allow for the introduction of CHP, an interpretive methodological perspective was not considered suitable for the research.

Another possible methodological perspective is Grounded Theory, an approach that draws on some of the basic ingredients of analytic induction. Grounded Theory is the development of a theoretical position, from a close inspection and analysis of previously unknown qualitative data (Glaser, B., & Strauss, A., 1967). The use of this methodological base would suggest erroneously, that there was no prior observation from which the research is derived. The epistemological basis of Grounded Theory is also closely associated with interpretivism, an approach that has already been rejected.

Critical Theory then offers an interesting angle to approach the research. In taking a closer look at the epistemological issues underlying the research, it is argued that one of the potential outcomes of this research is the understanding of the unintended effects of Government policies, as potential barriers that limit the use of CHP in SMEs. Such an understanding would involve the accumulation of 'facts' in the form of quantitative data and 'experience' in the form of qualitative data. It would necessarily involve a consensus of views and statistical data in the testing of the research hypothesis. The use of the Critical Theory methodology therefore allows the combination of some of the principles of Interpretivism and Positivism into a single methodology, whilst limiting the deficiencies of Logical Positivism and Interpretivism. Critical Theory argues for the combination of methods in the Social Sciences, including some aspects of Positivism and Interpretivism. Critical Theory therefore offers the perspective of a mixed methodology that incorporates both qualitative and quantitative principles.

5.3 Implications of mixing methodologies

There are other key considerations in the research, such as the mixing of methods and the effect that this may have on the overall research process. Mixing methods, with one method being dominant has become quite commonplace in modern qualitative research. Burgess, R., (1982: 67), takes the view that *"field methods that do not encompass observation, informant interviewing and sampling are seen as narrow and inadequate"*. There are of course differing and contrasting views on this issue, Branen, J., (1995:11), affirms that *"the assumption that combining approaches ensure the validity of data is naive"*. The justification for mixing methods in this research stems from the need to ensure validation of the data through triangulation. Triangulation would in effect be the use of different approaches for data collection, with the intention of achieving a wider but interlinked solution.

The supreme requirement for validity in data collection and analyses has frequently led researchers to adopt mixed methods for data collection. This is based on the notion that any one way of collecting data is likely to have its shortcomings as similar patterns of findings from different methods of gathering data increase confidence in their validity (Roberts, P., 1992:69). Working within a post-positivist paradigm, such as Critical Theory, it is argued that triangulation also facilitates and enables analysis which is both more complex and more meaningful (Perlesz, A., & Lindsay, J., 2003:25)

5.4 Overview of Data Collection Methods

A summary of the data collection methods is shown in Table 5.1.

Table 5.1: Methods used in collecting data in for the research

Actors in Implementing CHP policy	Data collection method
National Government	Semi Structured Interviews
Trade Associations	Semi Structured Interviews
Government Agencies	Semi Structured Interviews
Regional Authorities[31]	Semi Structured Interviews
CHP Expert Consultant	Semi Structured Interviews
Commercial Enterprises	Case study reviews National database analysis Survey Questionnaire/ data analysis

The methods used in data collection are further explained as follows:

(1) A case study analysis of those organisations that had received support under the Government's CHP Best Practice Programme.

(2) A computer analysis of the national CHP database that contained 30 data sets on each of the 8000 registered installations in the UK (Ofgem, 2001b).

(3) Semi-structured interviews with 7 CHP policy-makers in the UK.

(4) A survey questionnaire of 27 questions sent to 331 SMEs.

The case study reviews and the computer-based desktop analysis of the national CHP database were carried out in order to identify key characteristics of business use of CHP.

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[31] At the time of the research study UK Devolved Assemblies had not yet been established. Data was obtained from other policy makers for this category.

They offered an insight to the characteristics of those organisations that use CHP and the data was used to determine the scope of questions for the semi-structured interviews and the survey questionnaire. Semi-structured interviews and survey data collection were used as the main data collection methods. In developing the semi-structured interview questions, care was taken to ensure the open-ended nature of the questions to encourage discussion and to elicit any other relevant information. Silverman, D., (1997: 95), suggested that, "*qualitative researchers favoured open ended questions in order to try to understand the meanings attached to the responses*".

The design of the quantitative survey, carried out after the earlier semi–structured interviews, was influenced by data obtained from the analysis of the semi-structured interviews. The survey questionnaire was structured in a way that allowed for mathematical modelling, in order to inform the development of the Decision Support Systems. An element of qualitative analysis was also carried out with the data collected, in order to assist with the validation of the Decision Support Systems and to ensure triangulation in the research. The use of multiple methods of data collection provided the basis for a reasonable degree of confidence in the build up of a theory from the data collected as it offers results from different considerations, e.g. technical, financial, and organisational. It is also useful in the elimination of bias, by using different methods of data analysis, a benefit that is further discussed in Chapter 6.

5.5 Sampling Strategy

In determining a sample set for the research, there were two major considerations. First, there was the need to identify a sufficient cross-section of policy-makers and CHP operators with the ability to objectively consider the policy-making issues surrounding CHP use in SMEs. This was particularly difficult as many of discussions between experts for the implementation of CHP schemes are either dominated by the "community-heating"[32] lobby or by the larger industry CHP users. There is no particular forum for discussion of CHP issues relating to SMEs, as this business sector has not been given much consideration by CHP policy-makers. The focus for CHP has always been on the scope for its use in housing led community heating schemes or in larger energy intensive organisations, an anomaly that this study is seeking to address. The other consideration was to determine a suitable representative sample of CHP operators in the SME business sector, for taking part in the survey following the semi-structured interviews.

As a starting point, it was felt useful to gain an understanding of the key characteristics of what is considered to be a successful CHP scheme by the Government's technical experts, FES. This exercise was carried out in an attempt to identify any common or distinguishing parameters between the 20 case studies of good practice CHP demonstration schemes, which had received support under the former Energy Efficiency Best Practice Programme, 1993-1999, now re-branded as the Action Energy programme.

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[32] Community heating is the use of distribution networks to supply heat and electricity within a community. This system frequently incorporates a CHP plant.

A research study carried out by FES (EST, 2000), had suggested that SMEs with a turnover of at least 2.5 million pounds and an annual energy cost in excess of £50,000 per annum were more likely to require capital-intensive energy efficiency services such as CHP. It is therefore considered prudent that this already identified group of SMEs is used as a sample frame for the quantitative aspect of the research, as it is the most likely to require the installation of a CHP plant. In a previous study, FES (1997a) had also noted a likely number of small scale CHP installations of 500KWe-5MWe as about 1919 (Table 1.2).

In the UK there is only one Government recognised and authorised list of CHP installations. This is a national CHP register, which contained information on approximately 1553 CHP installations in UK organisations, at the end of September 2001. Ofgem manages this database and it is a publicly available document supplied in Microsoft Access format. The second stage sampling was carried out by a desktop analysis of all the data contained in the national database of all small scale CHP schemes registered in the UK. This method of determining the sample frame for small scale installations was considered the most objective way of sorting the original data set of 1553 organisations. The observations from the data collected in the two previous methods, were then used as a basis for conducting interviews with a representative of each of the industry sectors within the current governance structure for CHP as shown in Figure 4.1.

5.5.1 Piloting the Survey Questionnaire

Due to the potential size of the data that was to be collected from the survey, it was considered essential for pilot surveys to be carried out, in order to ensure that the responses would be of the required value. In order to determine the effectiveness of the questionnaire, it was decided that a one to one survey was to be carried out for the "stage one" pilot surveys. In this case, the respondents were requested to complete as many of the questions in the questionnaire without assistance, but in the presence of the surveyor. The time taken to complete the questionnaire was noted, as well as any difficulty in the interpretation of the questions.

The outcome of the stage one pilot was to reduce the number and scope of questions. The number of questions was reduced from 30 to 27. Subsequent stages of piloting the questionnaire, led to further refinement of the format of the questionnaire, the style of questions and a reduction of the number of sub-optional questions. A summary of the outcome of the pilot stages is shown in Table 5.2

Table 5.2 : Summary of Comments from Pilot Surveys

Stage	Organisation	Commercial Sector	Comments
1	Leisure Company	Leisure	Too detailed questions
	Water Utility	Sewerage	Time factor for responses
2	Leisure Company	Leisure	Questions too technical in nature
	ESCO (operating a Town Hall scheme)	Office	Some information on staffing issues requested, is not readily available
	Hotel operator	Hotel	Unable to provide adequate responses to environmental questions
3	Manufacturing Co.	Factory building	Questionnaire was fine
	Housing Association	Office	Time taken for completion, more than 10 minutes

The final questionnaire was then sent out to the following broad categories of business sectors and in the numbers already identified by the sorting process:

Leisure-----------------------241

Offices – ---------------------13

Water & Sewerage-----------21

Hotels--------------------------39

Other Industries[33]----------- 17

331

A covering letter accompanied the questionnaire, including an indication of an estimated time for completion. This was to avoid the respondent discarding the questionnaire at a first glance. The letters were sent with prepaid reply labels to be returned to the University within four weeks of posting. A copy of the letter sent to the potential respondents for the survey is shown in Appendix 5.1.

[33] Other industries include; aircraft maintenance, agriculture, pharmaceutical, brewery & freight forwarders.

5.6 Data collection and analysis

5.6.1 Desk top review of case studies

Published case study reports of CHP installations noted as good practice demonstration schemes were examined, to obtain an indication/trend of any common factors that may influence the decision for a CHP installation. The examination of the case studies acted as a precursor in identifying the common parameters that were to be considered when analysing the larger data entries in the national CHP database. It further complemented the statistical analysis of the national database in order to establish some of the key criteria for a typical small-scale installation. The organisations identified in the case studies were not surveyed or interviewed as they were not all SMEs. The logic of studying their case histories was simply to determine any common features or best practice parameters that could be used as a starting point of assessing or developing a good CHP installation profile for possible replication in SMEs use of CHP.

5.6.2 Statistical analysis of national CHP database

The data was initially sorted by small scale[34]/large scale CHP categorisation, then by industry and business sector types. This was done to eliminate all large-scale CHP installations and companies from larger business enterprises from the sample set. Graphical analysis of the final data set was carried out to establish common parameters within the data on small scale CHP. Reading

[34] A small scale CHP user is one that uses a CHP plant with the capacity to produce no more than 1MW of electrical power. A large-scale CHP user has a plant capacity greater than 1MW electrical capacity (ETSU, 1997a).

from 30 possible data entries, each small-scale CHP installation was sorted by the following 10 entries:

1. Date of commissioning of the CHP Installation
2. Economic sector of the industry e.g. food & drink
3. Size code of the CHP plant-Small (S), Large (L)
4. Maximum heat output of the CHP plant
5. CHP electrical output capacity (kWe)
6. Regional Electricity Company of the installation location
7. CHP plant supplier
8. Name and telephone number of the client contact for the installation
9. Location of the plant (premises location)
10. Address of the business operating the CHP plant.

5.6.3 Semi-Structured Interviews

Following the analysis of the national CHP database and the good practice case studies, a number of observations were made (see Section 6.3), which formed the basis for the semi-structured interviews. Prior agreement was sought from interviewees for recording interviews and assurances were given on the use of information for academic purposes. The principle of providing comfort to interviewees was prompted by Silverman (1997: 119), who suggests, *"the use of a tape recorder in semi-structured interviews is a useful tool as the recording and the transcript allow the analyst to return to the extract either to develop the analysis or to check it out in detail"*. A copy of the letter of invitation to the interviewees is presented in Appendix 5.2. Semi-structured interviews were held with individuals from different organisations with responsibility for developing and implementing national CHP policies.

The choice of the interviewees was based on the need to obtain a wide range of views from all sectors of the CHP industry. It was also felt necessary to interview at least one representative of the sets noted in the conceptualised GSS (Figure 4.4, Section 4.5). Organisations from which the interviewees were selected are shown in Table 5.3.

Table 5.3: Details of Semi-Structured Interviewees

Organisation	Policy Sector	Position of Interviewee
CHPA	Trade Association Actor Network participant	Director
DTI	National Government Actor Network participant	CHP Policy Manager
DEFRA	Regional Government Actor Network participant	Head of CHP Division
Ofgem	Government Agency Actor Network participant	Technical Director
CHP Consultant	Expert Panel Consultant Actor Network participant	Managing Director
Utility Supplier	Regional Electricity Agency Actor Network participant	Senior Planning Engineer
Thames Water Utilities[35]	SME CHP Operator	Chief Engineer

[35] Please note that Thames Water Utilities is a semi-autonomous business within the Thames water group.

In the course of planning the semi-structured interviews, the intention was to interview a CHP plant manufacturing/supply company. During the interviews with other policy makers it became apparent however that the influence of the manufacturers was limited with regard to policy issues for CHP. Indeed there were only two active small-scale CHP manufacturers in the UK at the end of 2001. These were importing packaged CHP units from Holland, Belgium and Germany, which is a reflection on the declining small scale CHP market in the UK. The limited effect of manufacturers on influencing CHP policy in the UK is also noted by Strachan, N. and Dowlatabadi, H. (2000: 13). They conducted research on the role of manufacturers in the promotion of CHP sales within the UK and concluded that manufacturers had a minimal influence on the policy development for CHP in the UK. Manufacturers are effectively motivated by lucrative financial contracts in which the risks of operation are passed on to the client and are not mindful of the need for policy changes.

From the level of attention being paid by the Government to issues regarding the supply & distribution of electricity and the responses from other interviewees, the importance of the RECs regarding their policy initiatives for CHP, became more evident. It was therefore decided to interview a senior member of staff in a REC. The interview of the representative of the REC was therefore the last interview conducted and included a series of more specific and related questions that had been identified from the transcripts of the other interviews. The information gained from the three data collection methods so far were then used to develop the survey questionnaire.

5.6.4 Survey Questionnaire

An initial approach was to follow the format of the questionnaire used by Christie et al., (1995: 5-14), in their research study. This was done on the basis that their research study was about assessing the decision-making process for the adoption of a wide range of cleaner technologies (including CHP) in SMEs. Their methodology had included the use of a survey followed by semi-structured interviews with technical experts. Their method was to conduct one-to-one interviews, combining semi-structured interviews with a questionnaire survey in a single process. Their method of data collection did not appear to be appropriate in this research, as outputs of this research were not to be entirely based on qualitative outcomes. It also prompted concerns about reflexivity in the research as the respondent may not feel that the questionnaire was been completed in entirely independently.

The survey questionnaire for this research was therefore designed to produce both qualitative and some quantitative responses in order to provide evidence to all three research objectives. The qualitative responses were to be used to triangulate the information gained from the semi-structured interviews. The quantitative responses would be used to develop variables in the analysis and determination of indices within the BDSS. The responses to the survey questionnaire were obtained by a postal survey. By eliminating the questions relating to large-scale industry and environmental concerns, the residual questions were amended to suit the issue of CHP installations within SMEs. A sample of the questionnaire is provided in Appendix 5.3.

The survey questionnaire was designed to address the following:

- Financial evaluation parameters for SMEs
- Level of in house expertise
- The level of awareness of Government policy issues regarding CHP
- Links between Environment Management and CHP installation
- Organisational aspects relating to CHP Installation
- Drivers for a decision to install CHP
- Decision-making process for CHP installation
- Satisfaction with CHP, reliability/operational risk, potential for repeat

5.7 Computational Tools for Data Analysis

The sample set for the questionnaire survey was determined by sorting the data contained in the national CHP database, by the use of Microsoft Access 2000. Simple frequency analyses were carried out using Microsoft Excel 2000. The data obtained from the Excel analysis was also used as the basis for developing questions for the semi-structured interviews with key policy-makers for CHP in the UK. By an evaluation of the sample set as noted in Section 5.5, 331 SMEs operating CHP schemes within the 5KWe-5MWe engine ranges were sent the final survey questionnaire. Statistical analyses were carried out on the data obtained from the survey using the Statistical Package for Social Scientists (SPSS).

5.8 Limitations of the data collection and analysis

The limitations of the methods used in the data collection are the diverse nature of the collected data and the various techniques required to analyse the data. The limitations of Microsoft (MS) Excel are in its abilities to share and merge data with Microsoft Word and Access. Transferring data between Excel and Word files required reformatting to suit page set-ups. Where amendments had to be made to Excel data, it required frequent page re-formatting. In using MS Access there was much difficulty in exporting generic data into Excel where 'if-then' macros were used. The reformatting of data required an advanced knowledge of the use of the MS suite of software products and an entailed extensive training exercise. With adequate training, the use of Excel for modelling and simulation exercises became a very useful tool in the research process.

As a research tool, NUD* IST v4 was found to be very powerful. It allowed for cross-tabulation of the transcript of the interviews and carried out very complex searches along with the basic textual and node browsing functions. The software is easy to use and saves time when carrying out such large and complex research studies. However, there are some disadvantages with the use of NUD*IST, mainly with its special type of formatting, which makes navigation through the software cumbersome. Interface with the MS Word programme was difficult and the procedures for preparing the text for importing into NUD*IST were very time consuming. There were no major difficulties with the use of SPSS, as it has been a tried and tested statistical tool. A further description of the computer software is included as Appendix 5.4 of this Thesis.

5.9 Ethics and Reflexivity in the Research

Each potential survey respondent was contacted by phone for an initial appraisal of the objectives of the survey and to formally request their acceptance to participate in the survey. This procedure was designed to obtain their commitment to the completion of the forms before despatch. It also proved extremely beneficial for obtaining updated information on the following data:

- Background information on the CHP installations;
- An update of the names, addresses and contact numbers of key officers.
- Information on the performance of the CHP systems in the database.
- Qualitative data on the operational characteristics of the CHP system.

All semi-structured interviews were recorded with the permission of the interviewees. The tapes were to be retained in a secure location with assurances given that they would be destroyed after final submission and acceptance of the Thesis. Participants were assured that the information would only be used for academic purposes and not for any commercial gain.

Reflexivity was also a key factor in the research due to the current occupation of the researcher within the CHP consultancy industry. Where data was to be obtained from projects in which the researcher had some influence or had carried out some previous work for the CHP owner e.g. in a sampling of the survey questionnaire for a Town Hall based CHP scheme, care was taken to ensure that the nominated respondent acted independently and the researcher's role in the exercise as was not identified. In that case the request for participation was made by the Director of Studies to the CHP operator. Details of the transcripts for the semi-structured interviews are included in the floppy disk attached to this Thesis.

5.10 Conclusion

The design of the research was directed at achieving a new policy framework for encouraging the use of CHP in SMEs. The research therefore sought to identify some of the key changes required to the current framework in order to achieve the research aim. Having identified a theoretical policy framework in Chapter 4 as an integration of both the GSS and the BDSS, the research was designed to allow for a closer examination of the parameters that would influence the performance of both these support systems. Table 5.1 shows a mixture of methods that comprised the data collection process, noting the relevance for each collection method to Figures 4.4 and 4.9.

In order to elicit adequate research data on each of the research objectives, the research process was subdivided into distinct data collection phases (Figure 5.1). The choice of policy makers included a spectrum of key personnel that were already actively in CHP policy development. This was particularly helpful as discussions of Devolved Administrations and the emergence of Regional Development Agencies were still in their infancy within Government departments. The design of the survey questionnaire included features that were useful in developing a "picture" of efficient and effective CHP installations and subsequently for the determination of performance indicators to be used in a Business Decision Support System. Although broadly based on a combination of other research designs (Section 5.6.4), this study was specifically designed to identify the economic, social and technical aspects relating to the use of CHP in SMEs, and for facilitation of the techniques used in analysing the results.

Chapter 6
Analysis of Results

6.1 Introduction

In previous Chapters the argument that there was a declining trend in the use of CHP has been based on discussions about the deleterious effect of NETA and partly on other unintended effects of Government policies (Section 1.2). These factors, combined with the theoretical discussions in Chapter 3, of the importance of improving the environmental performance of SMEs, led to the central aim of this Thesis; that a new framework is required in order to encourage the greater use of CHP in SMEs. Four data collection methods were used in order to identify the scope and interrelationships of this new framework. The data collection methods, based on a Critical Theory Methodology (Section 5.2) systematically allowed the build up of a theory, which in turn would form the basis of a new policy framework.

Each data collection method therefore sought to provide information on fulfilling the objectives of the research study, such that when the results were analysed on a collective basis, would lead to a new understanding of the policy initiatives required to encourage the increased use of CHP by SMEs. Another key aspect of the use of different data collection methods was the need to encourage triangulation and also to ensure robustness of the research conclusions.

6.2. Results from the data analysis

6.2.1 Review of case studies

The data collection commenced with a review of 20 best practice CHP case study publications by the DTI's former Energy Efficiency Best Practice Programme (EEBPp). A purpose of this exercise was to obtain an initial view of the particular characteristics of the CHP project that warranted a "best practice" example. Another reason for this data collection method was to identify any common criteria in the business operations or in the way the CHP schemes were developed across the businesses studied. This data would assist in creating a framework required for implementing successful CHP schemes. Table 6.1 is a summary of the key parameters of the cases reviewed.

Table 6.1: Key Details of Cases Studied in the Review:

Company	Location	CHP Capacity Mwe	Energy Saved per Year (TJ)	Payback Yrs
Land Rover	Solihull	8.0	11.2	5.5
John Thompson	Belfast	2.0	94.4	3.0
Courtaulds	Grimsby	3.0	98.2	4.75
Kodak	Harrow	8.0	692	4.4
Conoco	Grimsby	10.0	818	2.0
Smith, Stone & Knight	Birmingham	3.63	155	3.0
Rigid Paper Products	Selby	3.66	63	3.0
Cyanamid	Gosport	3.5	130	5.5
BPB Packaging	Purfleet	3.6	226	3.3
ECC International	St Austell	7.5	337	3.6
Midlands Health Authority	Edgbaston	3.6	118	3.0
Arjo Wiggins	Dover	9.4	540	5.4
Safeway	Middlesex	0.2	0.4	4.4
United Biscuits	Manchester	1.0	27	5.3
Midland Meat Packers	Northampton	0.5	4.9	5.0
North West Water	Manchester	5.2	7.5	4.5
South West Water	Exeter	0.6	9.2	3.2
BPB Radcliffe	Manchester	1.0	1.5	1.7
Inenco Group	Manchester	1.0	27.0	5.26
Courtaulds	Grimsby	0.6	1.1	2.1

The case study review identified 7 common features:

(1) The payback periods were less than 6 years.

(2) The schemes were carried as part of a plant replacement project.

(3) Government grants and third party finance were obtained.

(4) The CHP sizing was a factor of the financing package, not demand led.

(5) External technical experts were used to develop the schemes.

(6) The schemes were carried out at locations owned by the client.

(7) There was no data on the level or proportion of CO_2 savings.

The review noted that 'prima facia', the CHP schemes were deemed successful on the basis of acceptable payback periods between 1.7 and 5.5 years. These payback periods could not however have been achieved without significant Government support in the way of financial grants. Whilst meeting the financial need for encouraging the installation of CHP units, the grants also afforded the client a way of addressing operational concerns, as well as reducing the cost of purchasing electricity from the national grid.

An example of the operational benefits is the Cyanamid site in Gosport, where the use of CHP solved a problem of network enhancement. CHP was also used for waste minimisation in the cases of Midlands Meat Packers and South West Water. A different payback calculation could also have shown much reduced periods if antecedent benefits such as waste improvements and less downtime were included in the cost benefit calculations.

Evidence of the antecedent benefits was noted in the Courtaulds Project, Grimsby, in which CHP was installed as part of a new method of improving the production process. On energy savings alone the payback for installing the CHP system was 4.7 years. When the increased value of the final product is taken into consideration, the payback period was reduced to 2.1 years. Although the review highlighted short payback periods, it was noted that there was a considerable amount of scope for using larger CHP engine sizes that would produce a larger proportion of the site's electrical requirements. In addition there would have been a larger heat output for use on the site. The key factor in the sizing decision appeared to have been the availability of financial assistance which could in turn be linked to the minimisation of the company's own capital.

If all CHP projects require grant support, then it could be inferred that CHP is considered by SMEs to be a risky investment even where its technical need is proven. It was also noted that these CHP schemes were part of larger engineering projects, which invariably necessitated the use of external experts. It was clear however that the use of the CHP was initiated by the client company and that the schemes were carried out at locations owned by the client. The identification of these common features prompted the view that the use of CHP in businesses may not be directly related to the reduction of grid electricity demand (Energy Efficiency) or to the use of CHP for heat production. They suggested that there were driving factors; the reduction of electricity costs or and prudent financial management at a time of plant replacement.

The theoretical perspective developed from this review was that the installation of a CHP system offers a positive potential for demand management when based on commercial considerations. The two key parameters for the decision as to whether a proposed CHP project would be successful appear to be it's economic return and its technical performance; in terms of the electricity it produces. By combining the availability of grants and external expertise it was possible to obtain reduced electrical grid reliance as well as financial viability by the introduction of new CHP plant. Some of the cases reviewed, i.e. 5 of the 20, had CHP units larger that 5Mwe and as such were not within the DTI's definition of small scale CHP plants, normally associated with the operations of SMEs. These studies were however reviewed as there are limited publications of best practice CHP case studies for SMEs, in order to obtain an extensive picture of the CHP use in business operations. The reason and relevance of conducting the review with some larger company data, was also that it might also offer some validation of any theoretical conclusions for the Small scale CHP operations, as well as an opportunity of providing 'signposts' for other key considerations in the use of CHP in SMEs.

The information gained from the case study reviews would be used to develop subsequent arguments relating to the 1st and 2nd research objectives, in Chapter 7.

6.2.2 Analysis of SME operated CHP schemes in the national database

6.2.2.1 – Technical Analyses

The purpose of analysing the CHP related data for SMEs was to make an assessment of whether there ware any significant external factors that would influence the use of CHP by an SME. Examples of these external factors are the location of a business within a Regional Electricity Company (REC) area, the economic sector of the SME, the engine supplier or the peculiarities of the business sector. The data entries are noted Table 6.2:

Table 6.2: Data entries in the Ofgem national CHP database

Organisational	Technical	External Data
Business Name	CHP power output	Details of REC
Date data collected	CHP heat output	Engine supplier details
Business Sector	CHP size i.e. large/small	Date Engines commissioned
Economic Sector	Engine Supplier details	

The Ofgem database contained information relating to 1551 installations, in some cases for organisations managing more than one CHP installation, such as Hotels. An initial sequence in the data analysis was to segregate the data in order to eliminate all large scale CHP installations i.e. > 5MWe. Subsequent data segregation led to the data being "cleaned" such that an objective analysis was carried out using the technical and external data sets.

A number of statistical assessments were then carried out using simple bar charts and histograms for comparative purposes between business sectors, economic sectors, RECS, engine suppliers etc. This was done in order to assist in the identification of patterns, or trends within and between sectors. The results of the data analysis are further explained as follows:

Chart 6.I:

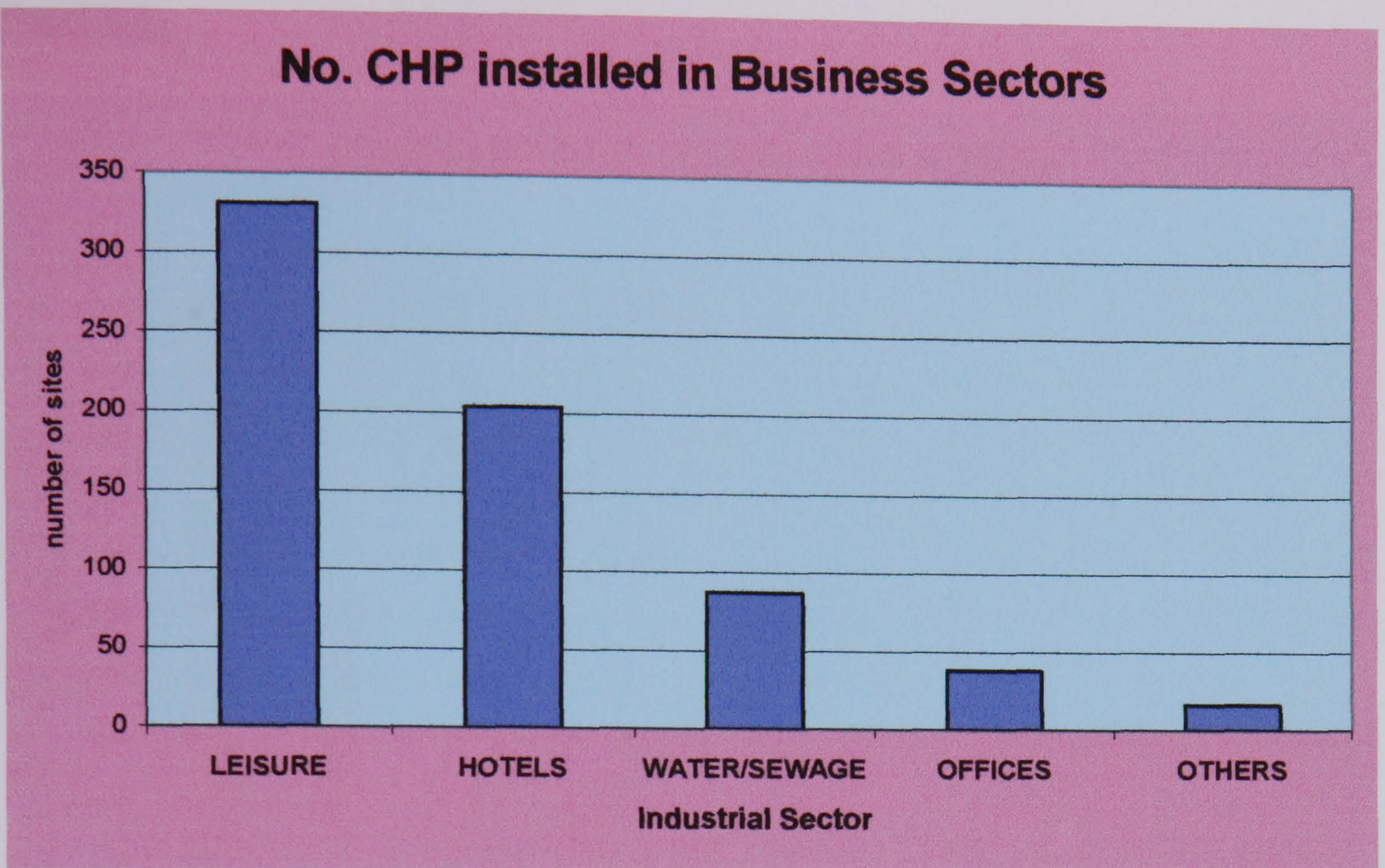


Chart 6.1 shows the spread of CHP use across six principal business areas. The business sector "other" includes data for building use, managed by businesses in Agriculture, Airport Authority, Manufacturing and Retail. It shows the number of CHP systems installed per business sector, identifying a pattern of CHP take up for each business sector. The significance of the Chart 6.1 is that it epitomises the business areas in which small scale CHP use is prevalent and would therefore warrant particular attention in the development of a supportive CHP policy framework. The Chart also sets out a starting point for understanding the scope of small scale CHP use by SMEs and the context of the subsequent data to be collected.

Chart 6.2:

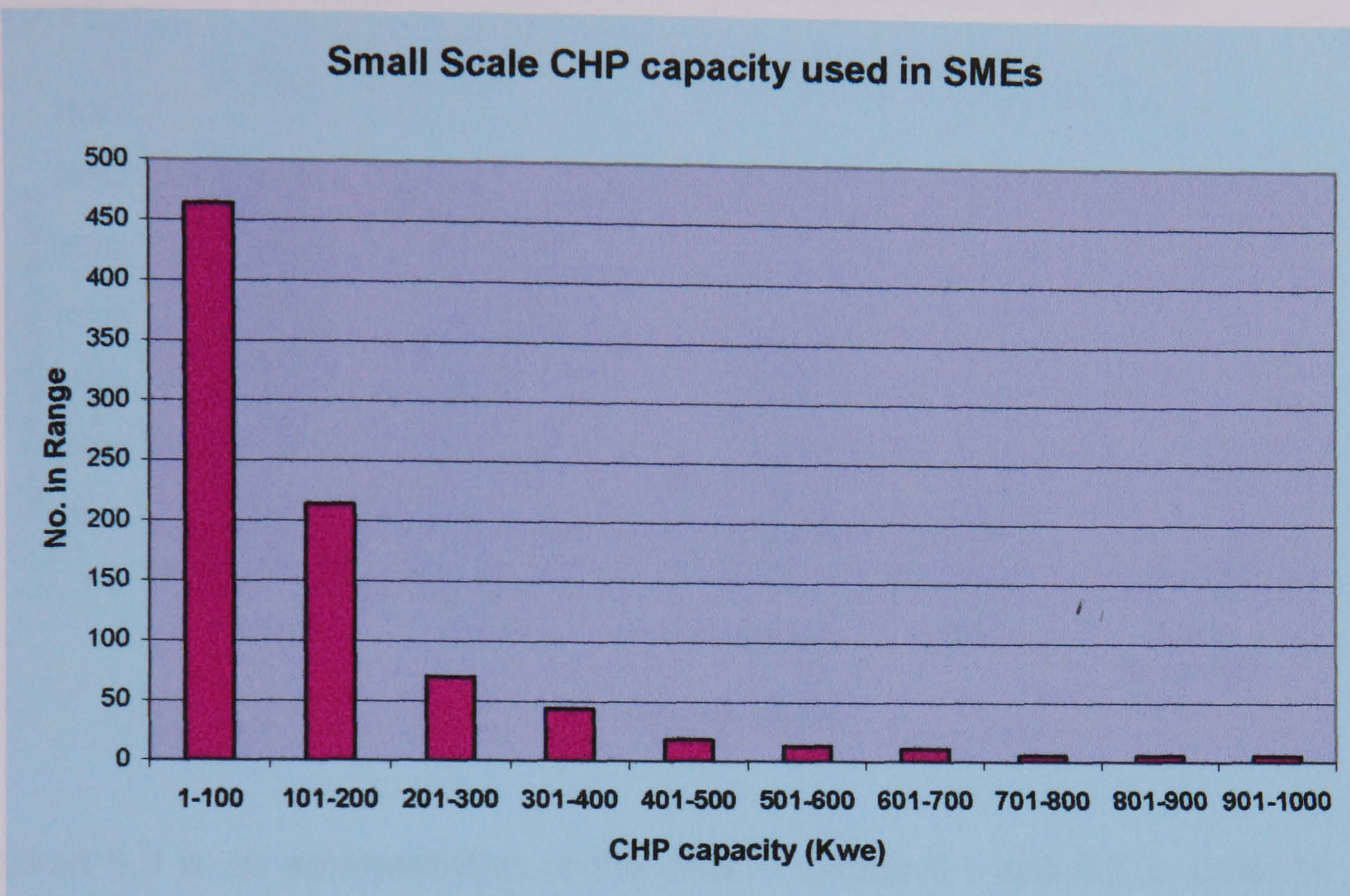


Chart 6.2 is an indication of the range of CHP sizes used by SMEs, noting that the majority of CHP engines are in the range of 100Kwe to 400Kwe. It also indicates that there was a reducing scope for CHP engine sizes of about 1Mwe used by SMEs. The number of CHP units above 1MWe was also noted as fairly insignificant. Chart 6.2 also emphasises the importance of ensuring the ready availability of the predominant range of small scale CHP engines (100Kwe to 400Kwe) in the UK. This Chart has particular significance when considered in conjunction with the results presented in Chart 6.4.

Chart 6.3

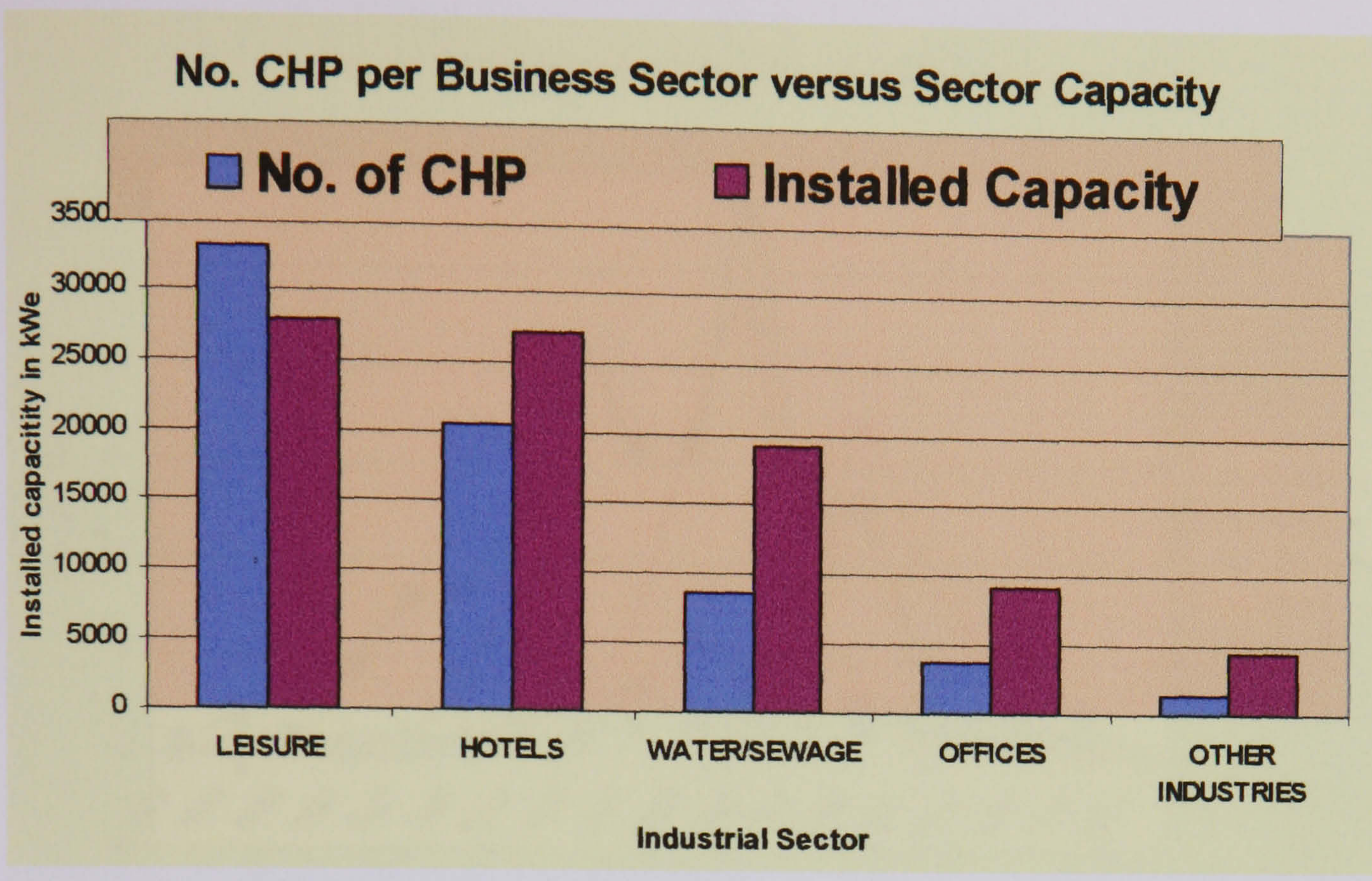


Chart 6.3 is an amalgamation of the data in Charts 6.1 and 6.2 in order to present a clearer picture of the capacity range in each sector, compared to the number of installations. It shows that the Water/Sewerage sector had a greater proportion of CHP capacity in relation to the number of units, followed by the Offices and then Hotels. The Leisure sector, although having the largest number of units per sector did not offer a high capacity factor as the other principal sectors. A strategy for targeting increased CHP capacity should therefore offer a priority to the scope for increasing use of CHP in the Water/Sewerage and Office business sectors. The Chart could also be interpreted to imply that the lower range of CHP sizes is used in the Leisure sector. Consideration should therefore be given to the scope for increasing the unit capacity sizes used in Leisure Centres where the demand allows. Planning regulations relating to the new developments in these business sectors should also be a requirement for the "de facto" use of CHP systems.

Chart 6.4

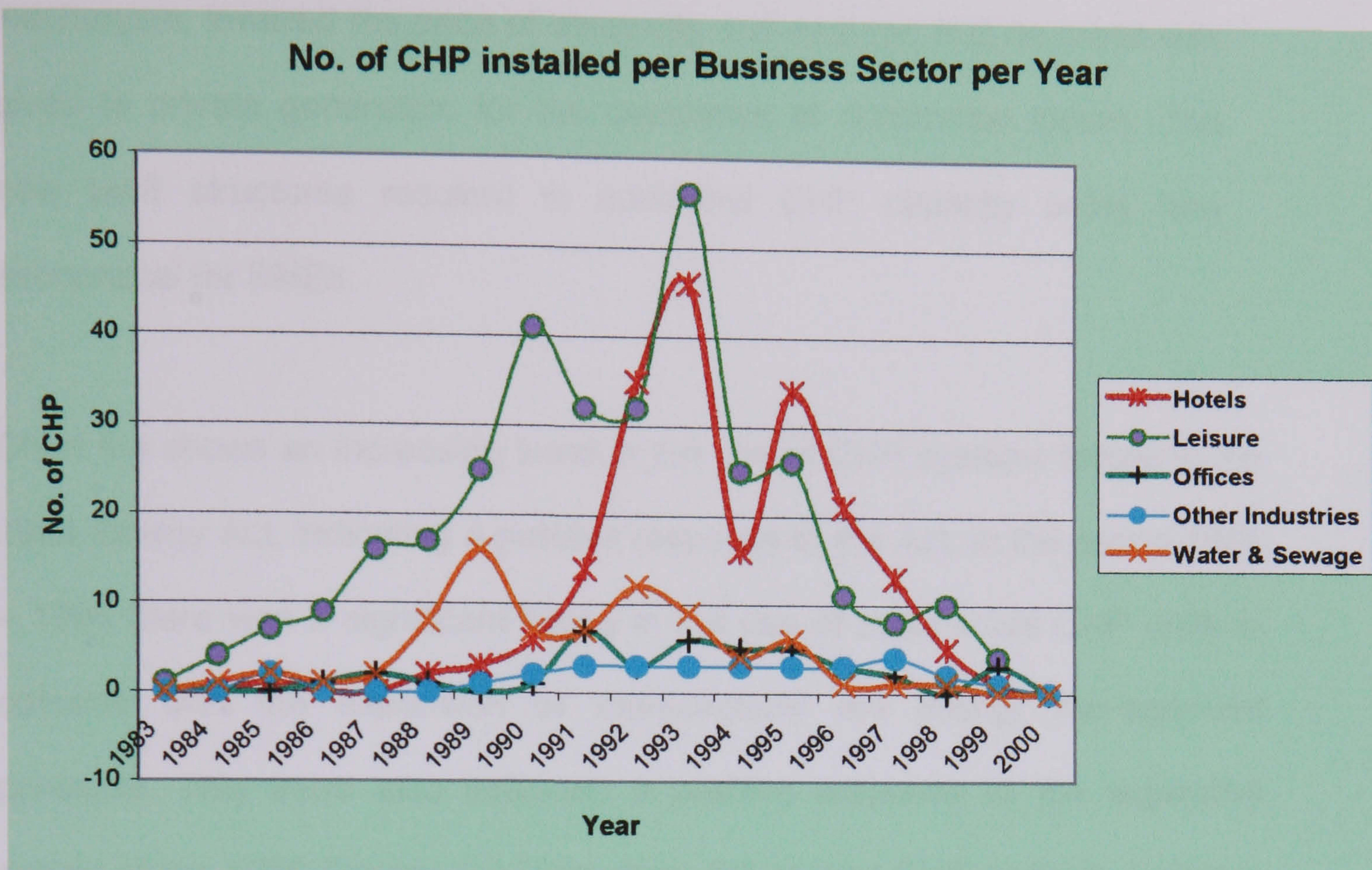


Chart 6.4 shows the number of small scale CHP units that were installed in the 5 business sectors, each year between 1985 and 2000, during three legislative periods that had significant effects on small scale CHP use in the UK. The legislative frameworks could be identified by the periods following new energy legislation in the UK, between 1980 and 2003.

(1) Energy Act 1983 – Providing the tacit right of small CHP generation to be embedded with the national power grid.

(2) Energy Act 1989 – Allowing RECs to control the tariff structures of power sales/buy back rates thereby dictating success or failure.

(3) Utility Act 2001 – The introduction of NETA as a new trading control mechanism, lowered the price of electricity and ensured that no credit was given to private generators for the avoidance of distribution losses. The new tariff structures resulted in additional CHP capacity being less economical for SMEs.

Chart 6.4 shows an increasing trend in the use of CHP systems following the 1983 Energy Act, indicating a positive response to the Act. In the period 1989 – 1996 there was a significant hiking in the use of small scale CHP units to coincide with the expansion of manufacturer led energy management contracts. This trend also indicated a positive response to the legislative nature of the 1989 Energy Act. The sharp fall of new CHP capacity between 1997 and 2000 could be explained by the period of low government support for CHP and the lack of a coherent strategy surrounding the period of the change of Government in the UK. The labour Party's stated intention (M Meacher, 1997) to introduce NETA and the subsequent slow metamorphosis, of NETA, could also have hindered the growth of new CHP capacity, a trend that continued to 2002 (DT1,2003a).

The theoretical perspective derived from this Chart is the need for a longer term strategy, that would be embedded outside of party political dogma and that would not be subjected to periods of extended market indirection.

Chart 6.5

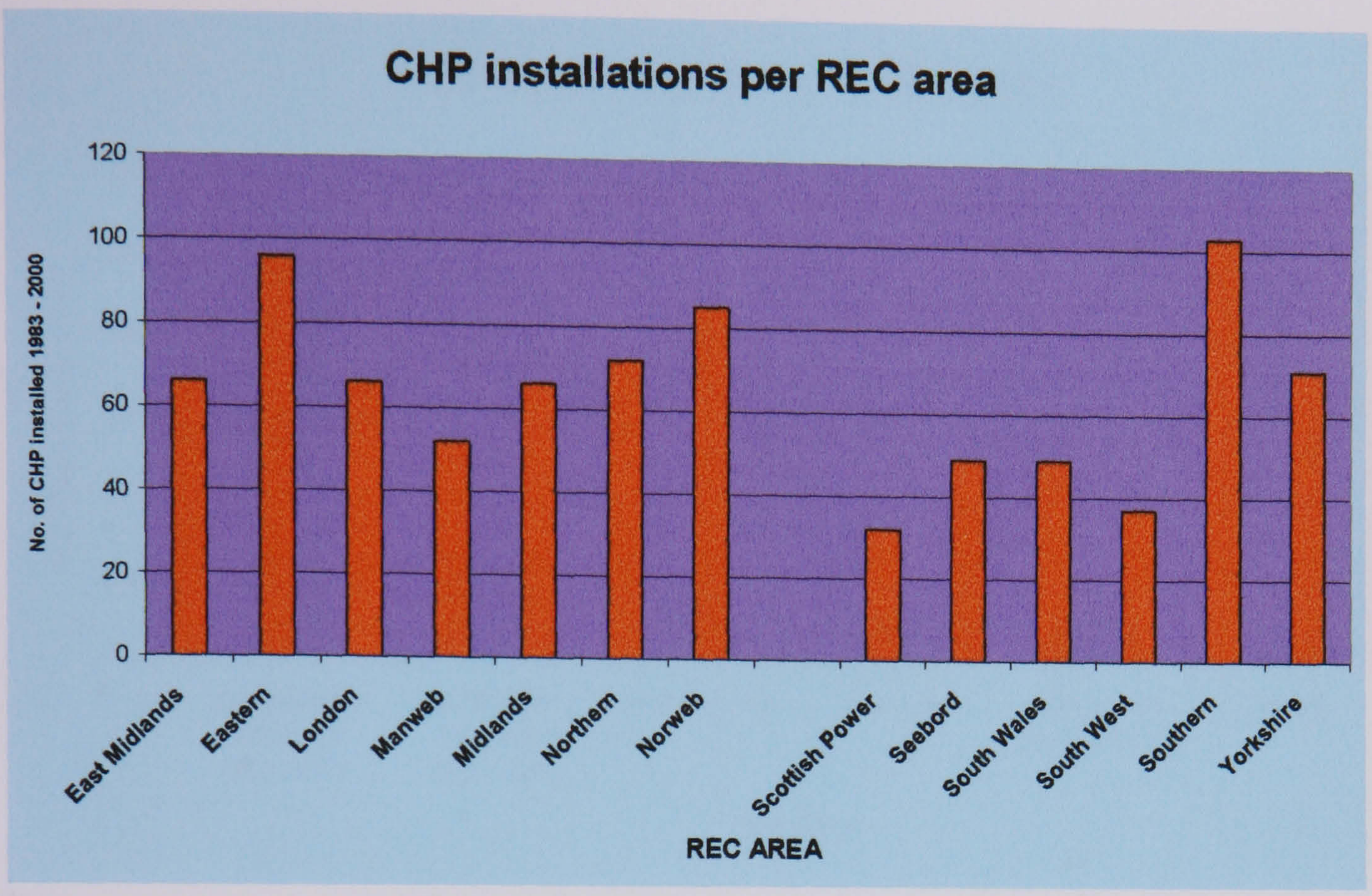
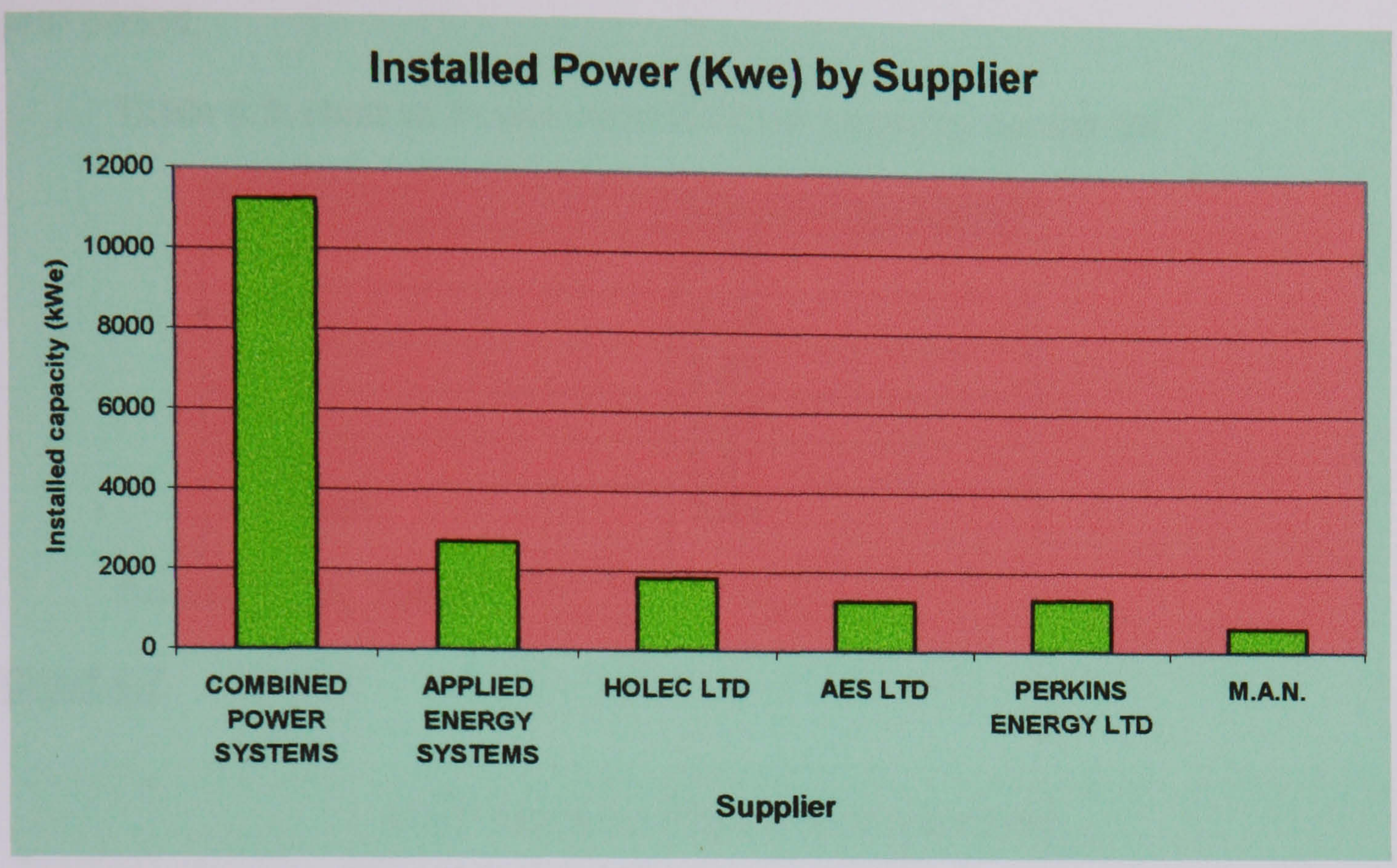


Chart 6.5 is an indication of the spread of CHP units across the RECs. The purpose of the chart was to identify any region of significant CHP inactivity. The Chart does show sufficient CHP activity in every REC across the UK. It cannot therefore be concluded that RECS are restricting the use of CHP in their regions. It also provided an indication that the RECs are unlikely to be a significant barrier to the proposal of a new policy framework for the increased use of CHP.

Chart 6.6 shows the number of CHP per engine supplier and raises questions relating to the current availability and manufacture of CHP systems in the UK, as 4 of the suppliers noted in the graph are no longer in the CHP business. In the small-scale CHP sector, there are currently 2 predominant small scale CHP manufacturers in the UK; COGENCO (formerly HOLEC) and ENER-G (formerly Combined Power Systems).

Chart 6.6



These manufacturers have about 80 % of the small scale CHP market between them (the 20% balance is directly imported). This is because the market for small scale CHP is currently shrinking as it is less profitable (CHPA, 2002a). An example of this is the change in ownership of HOLEC, which became NEDALO in the 1990's and having been under increasing financial pressure, was subsequently restructured as COGENCO after a management buy out.

Chart 6.7 shows the relationship between the heat and power output of the CHP installations in the business sectors. This significance of the Chart is to examine the predominant output form the CHP engine and in a sense the output driver. The basis of the significance is that for many small scale CHP engines, the heat /power ratio is between 1.5 and 2.0. Government statistics on CHP capacity (Table 6.3) indicates a national average of 3.06 over a 5 year period.

Table 6.3: Heat to Power ratio for CHP capacity on the UK

Year	Heat /Power Ratio
1998	4.15
1999	3.78
2000	2.51
2001	2.53
2002	2.31
Average	**3.06**

Source: (DTI, 2003)

Chart 6.7

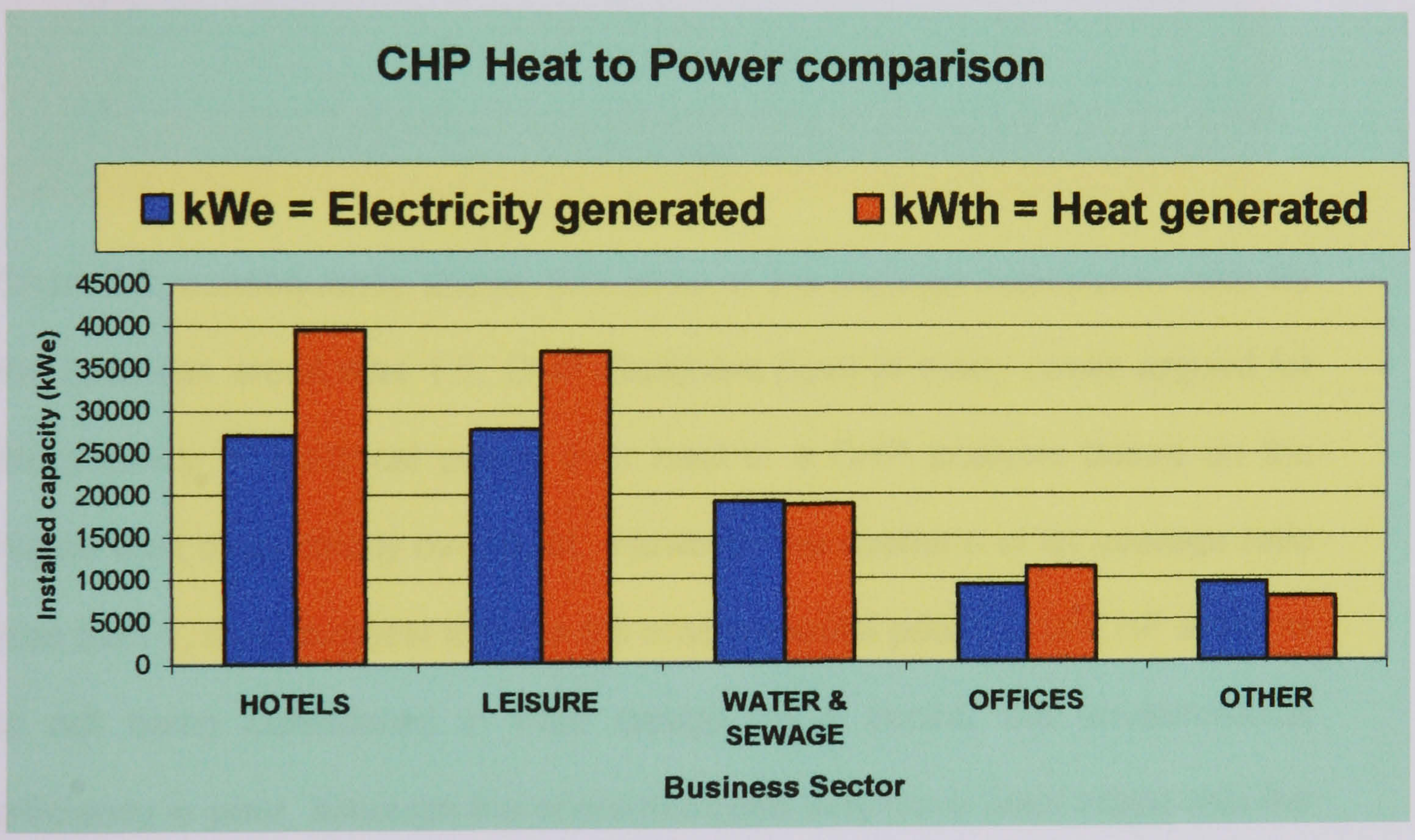


Chart 6.7 however shows ratios lower than 1.5, which indicates a lower proportion of heat output from these installations than the national average. In order to obtain a better understanding of the bias towards power, the averages of the ratios in for each installation in a business sector were further compared in Chart 6.8.

Chart 6.8

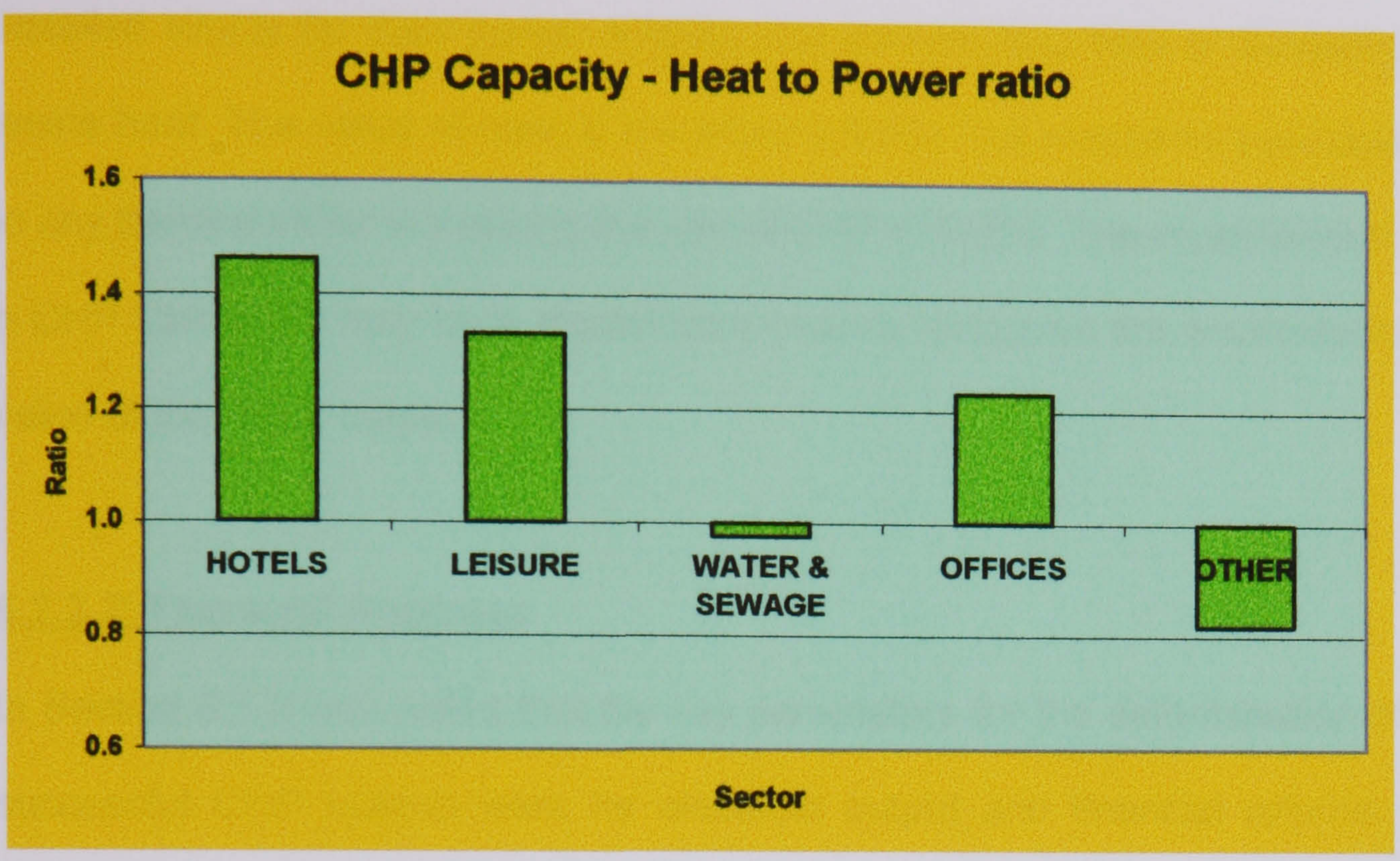


Chart 6.8, consequently shows that none of the average heat/power ratio for the business areas was 1.5. CHP designers have in many cases argued for the primacy of electrical power over heat in a CHP analysis based on the higher cost of electricity over heat. However the scenario of an average ratio less than 1, must suggest that the full environmental potential of CHP systems is not being considered in their design. In a sense, the environmental efficiency is poor, although the economic case may have been made with the availability of Government grants and third party funds.

The graph therefore suggests a much greater bias for small scale CHP use towards electrical output as the significant parameter and that not sufficient emphasis is placed on the value of heat. This analogy is further highlighted by the 'Other' business sector where the capacity of heat is much lower than that of electricity.

An examination of the raw data shows that in some cases, CHP units are installed simply for their power outputs and the resulting heat is dumped as waste heat. The value of heat is therefore a factor that should be considered in any framework for increasing the use of CHP in SMEs. The consideration of a CHP Obligation may be a mechanism used to recognise the environmental value of the Heat output.

6.2.2.2: Financial Analyses

In Section 6.1 It was noted that the key parameters for the determination of a successful CHP system were its electrical output and financial returns. In order to gain a better understanding of the effect of financial instruments on the use of CHP by SMEs, a number of financial tests were carried out using national energy price data (DTI, 2003a) and national financial data published by the Government (HM Statistics Office, 2003).

Chart 6.9 considers the effect of primary utility fuel prices on CHP use, in order to examine any changes that primary gas or electricity prices may have on the use of CHP by SMEs. It also examines the data to see whether a fuel price trend has a relationship to new CHP capacity. The Chart shows a reducing electricity price trend, a relatively stable gas price and a discernible reduction of CHP capacity over the period 1992-2002.

The graph does not however lead us to derive any empirical relationship between reducing electricity prices and CHP capacity. Ilex (2002) had however suggested that a better way of determining any relationship between fuel prices and CHP use was by a comparison of the effect of spark spread[36] on capacity.

Chart 6.9

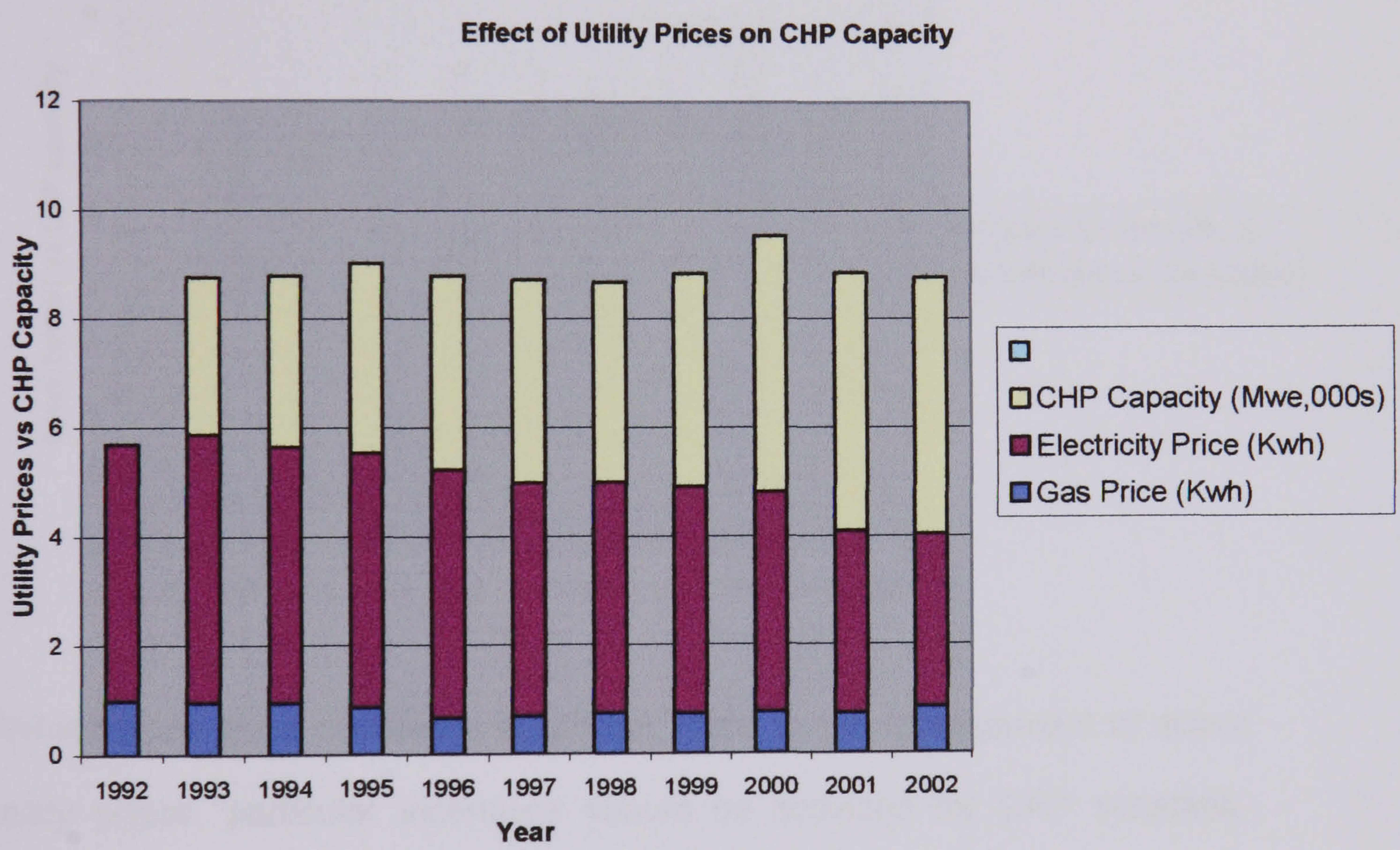


Chart 6.10 therefore shows the effect of the spark spread on the installed CHP capacity for the period 1993-2002. The graph shows a gradual spark spread increase between 1993 and 1999. During this period there was also a general increase in the capacity of CHP installations. A more marked drop in spark spread occurred between 1999 and 2000, which coincides with a

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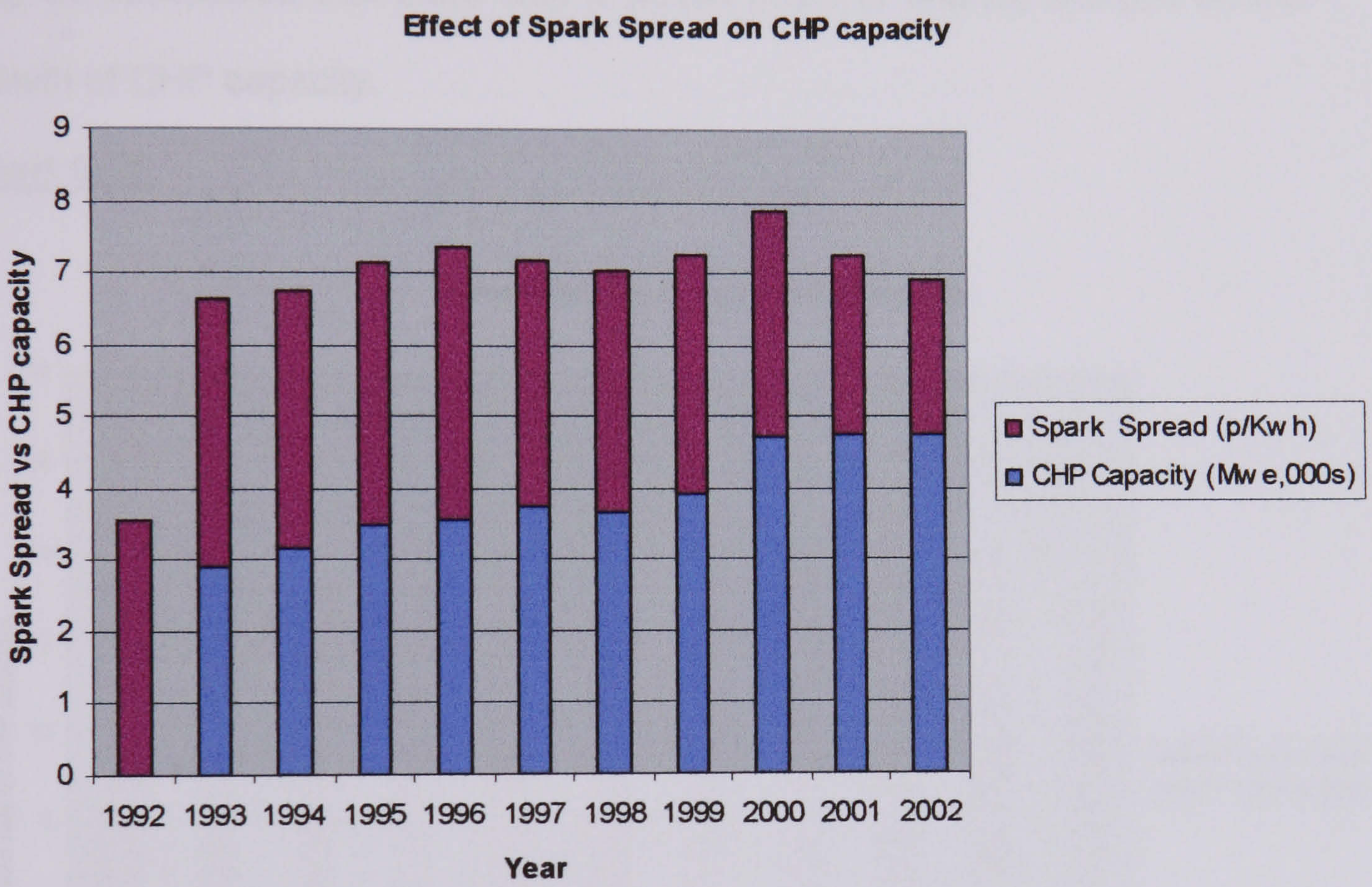
36 The spark spread relates to the difference between the unit (kWh) electricity price and the input gas price (adjusted for efficiency) to produce one unit of electricity. (DTI, 2003)

significant halting of CHP capacity growth in 2000 and a gradual decline to the year 2002.

It could be interpreted that there is a limiting spark spread value for the growth potential for CHP capacity and that there should be a policy for this limiting value not to be breached, if CHP market expansion is to be encouraged.

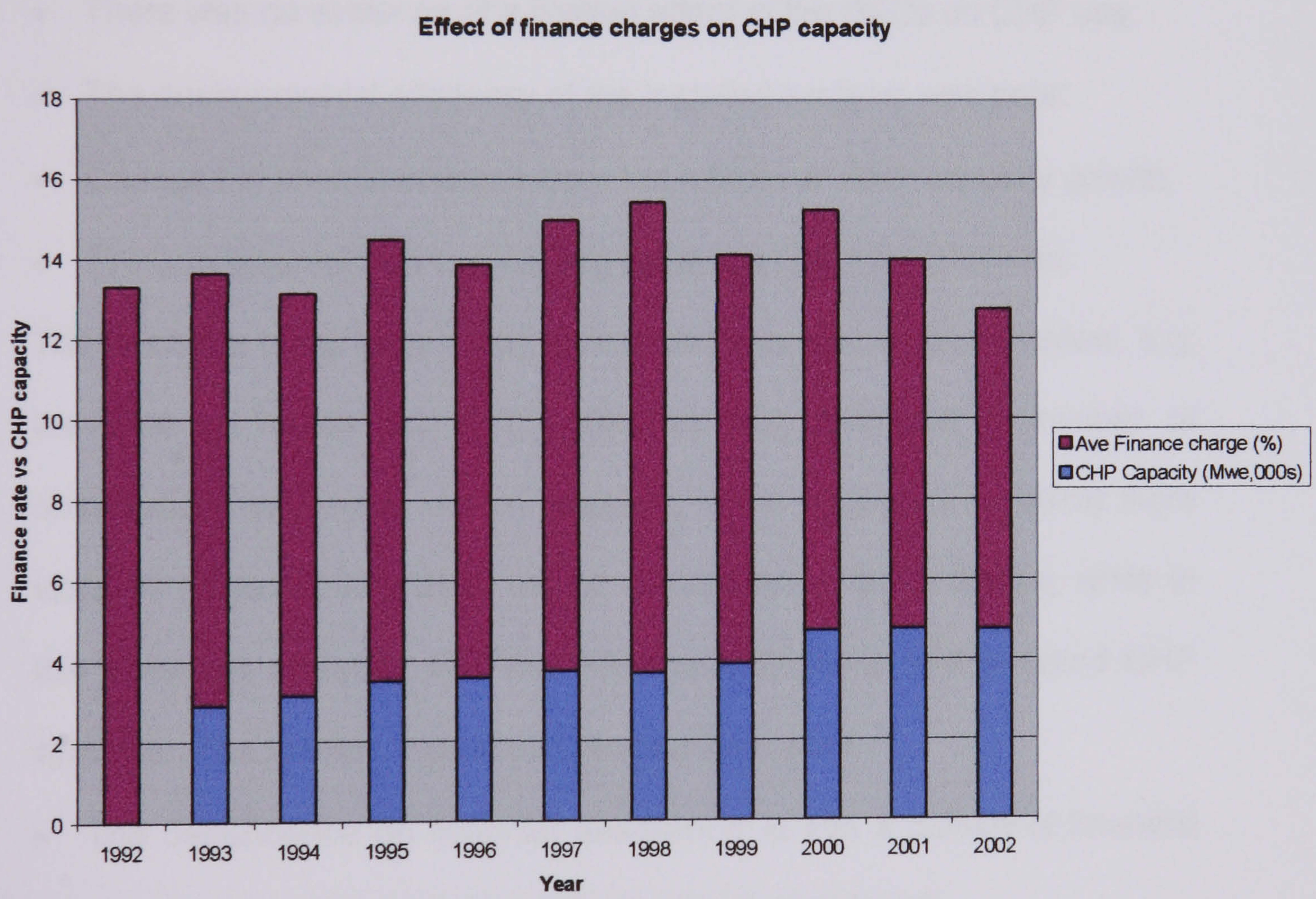
Chart 6.10



Whilst these fiscal measures would not relate to the management of actual utility prices, particular incentives should be provided for CHP schemes, based on a tracking of spark spread, to encourage its use by SMEs. There is also some resonance with a call by the CHPA (CHPA, 2003) for a CHP Obligation which, would be based on a limiting spark spread value. Chart 6.11 considers the effect of commercial interest rates on CHP use - in order to examine the sensitivity of the financing costs on CHP use.

The Chart shows that CHP capacity rose gradually during 1992-1998 when finance charges rose sharply and that CHP capacity did not subsequently reflect the fall in finance charges from 1998. From a theoretical perspective, it may be considered that there was a limited effect of finance charges on the growth of CHP capacity.

Chart 6.11



It may also be inferred that the increased CHP demand was driven by engineering considerations in terms of plant replacement and the availability of financial assistance. Whilst third party financing could also be a factor, its effect would be reduced in relation to finance charges on CHP capacity. In many cases it may have a lagging effect due to the time span for developing CHP projects, typically about two years (EST, 2003).

6.3 - Summarising the implications of the data collected

The analysis of the Ofgem data led to the following conclusions:

- Small Scale CHP installations are mostly found in 5 business sectors.
- Some organisations operated more than one CHP scheme
- The pattern of CHP use closely mirrored key political milestones.
- There may be a limiting effect of the number of suppliers on CHP use.
- There was no evidence of a limiting effect of the RECs on CHP use.
- The environmental efficiency of the installed systems was poor.
- Changes in finance charges were not a factor in CHP capacity growth.
- The spark spread, up to a limiting value is a factor for CHP use.

The evidence in the case study review and previous literature review, e.g. the data in Tables 1.2 & 1.3 (Section 1.2), prompted a number of observations or themes. As an example, in the FES report (1997a) there were 10 projected key SME sector classifications for CHP use, while in this database analysis, only five SME classifications had installed CHP systems. The themes, expressed as questions were:

- The dependence on financial assistance; is this a culture of financial modelling as the only basis of CHP project appraisals?
- The regular use of consultants: is this an indication of a lack of knowledge or non availability of appropriate analytical tools for SMEs?
- The value of heat is minimised; is this because CO_2 or environmental efficiency is not a driver, or a lack of awareness by SMEs?

Information gained from the data analysis would be used to develop arguments relating to the 2nd & 3rd research objectives, in Chapter 7.

6.4 Analysis of data obtained from semi-structured interviews

In Section 6.3 the data obtained from the case study review was used as the basis of identifying those parameters to be examined from the Ofgem database. In this element of the data collection exercise, the data collected from the two previous exercises were crystallised into themes and were expressed in the form questions and statements to CHP policy makers. These statements were also guided by Government fiscal policy initiatives in the Utility Act, 2001.

Whilst every attempt was made to remain objective about these observations, the discussions in Section 2.6 and the data colleted so far, have highlighted some concerns about the effect of Government policy on CHP capacity growth. It became obvious that a number of these observations may be representing limiting factors for CHP e.g. the regular use of Government grant support for CHP schemes, may suggest that CHP schemes were not economically viable. The lower level of penetration of CHP in sectors identified by FES (1997a) as having a significant potential for CHP schemes, would imply a communication gap between SME managers and the Government. It was therefore felt necessary to interview personnel with a significant influence on the development of CHP policy in the UK in order to obtain comments on the data collected so far. This was also to offer an opportunity for them to analyse the policy constraints (if they perceive any) to the use of CHP in SMEs.

In planning the interview format, an open interview technique based on themed statements was preferred, as it was thought to offer a good chance of encouraging discussion from Interviewees (Silverman, 1997). There was also a need to crystallise these observations into identifiable themes, such that some structure would be maintained in the interview process. Developing themes was also a useful mechanism for ease of qualitative data analysis using NU*DIST v4.

6.4.1 Observation 1- Organisational

One of the key obstacles to the uptake of CHP in SMEs, is the difficulty in the decision making chain to have an independent understanding of the technology. As such, CHP schemes are frequently developed through the use of third parties, such as specialist consultants. Whilst consultants are in themselves useful, they frequently indicate that a scheme is feasible so that they could maintain their commission. Grants for consultancies are often linked with the client having to pay a contribution and frequently having little/no understanding of the appraisal.

There is a need to develop a decision making mechanism for middle managers who can then be in a position to carry out an initial appraisal before a consultant is appointed to carry out the detailed study or design. The number of independent consultants is few in the UK and over the past 6 years, engine manufacturers have been more active in the design/installation of schemes. They, of course have a vested interest in selling engines. If CHP is therefore to be fostered or pushed on to an unwilling market, it will not achieve the full potential, as envisaged by the Government's targets.

6.4.2 Observation 2-Technological

The majority of CHP feasibility studies and designs are carried out within an independent CHP framework, i.e. not considering other energy efficiency aspects such as tariff analysis, fuels switching, low energy lighting/power schemes. This has traditionally been done to ensure that the maximum benefit is derived for the study/design for CHP. With falling electricity prices, it is suggested that CHP would not be such a viable technology, if there was a requirement to maximise on the potential for other energy efficiency measures, prior to a consideration of a CHP technology.

Perhaps, there has to be a benchmark for energy efficiency in an industry, before CHP can be considered. All SME managers should be required to have shown consistent achievement of this energy efficiency performance level, before CHP is installed. This would ensure that all CHP schemes provide the best value for money for the client. Clients would then feel assured that what they are getting from CHP is what they require. This would considerably enhance the credibility/value of CHP to the market.

6.4.3 Observation 3: Government Policies

CHP schemes are normally designed to offset an electrical load or a heating load. More frequently the electrical load is the driving factor as it has tended over the years to be more valuable than heat. An analysis of installed CHP systems does however suggest that the installed capacities do not form a sufficiently significant proportion of the site load. The CHP system would then be considered installed, not with the aim of offsetting the imported power. There are however, other benefits associated with CHP, such as Regional Environmental targets, Corporate Environmental reporting, additional tariff options, and financial grant support.

There is currently the benefit of the exemption from the Climate Change Levy, Business Rates Relief and Enhanced Capital Allowances and in 2005, EU Emissions Trading Scheme (Section 2.6). The implication of the use of economic instruments is for the market to encourage the use of cleaner technologies such as CHP, in order to address environmental concerns. It may therefore be that CHP is installed in cases where the environmental benefits are less significant than the economic/business requirements e.g. removal of new boiler plant to be replaced with a CHP plant. Some of the fiscal measures may not last for more than a few years in which case inappropriate CHP schemes could have been developed, which would not be in the long-term interest of the CHP industry. We are also not clear of the future role of Local Authorities or for that matter the proposal for Devolved Administrations and Regional Development Agencies with respect to special planning and development powers.

The transcripts obtained from semi-structured interviews were analysed by NU*DIST v4 using the Index Tree in Figure 6.1. The results of the analysis are presented as comparative assessments of statements, in Table 6.4.

Figure 6.1: Index Tree Nodes used for coding the interview transcripts

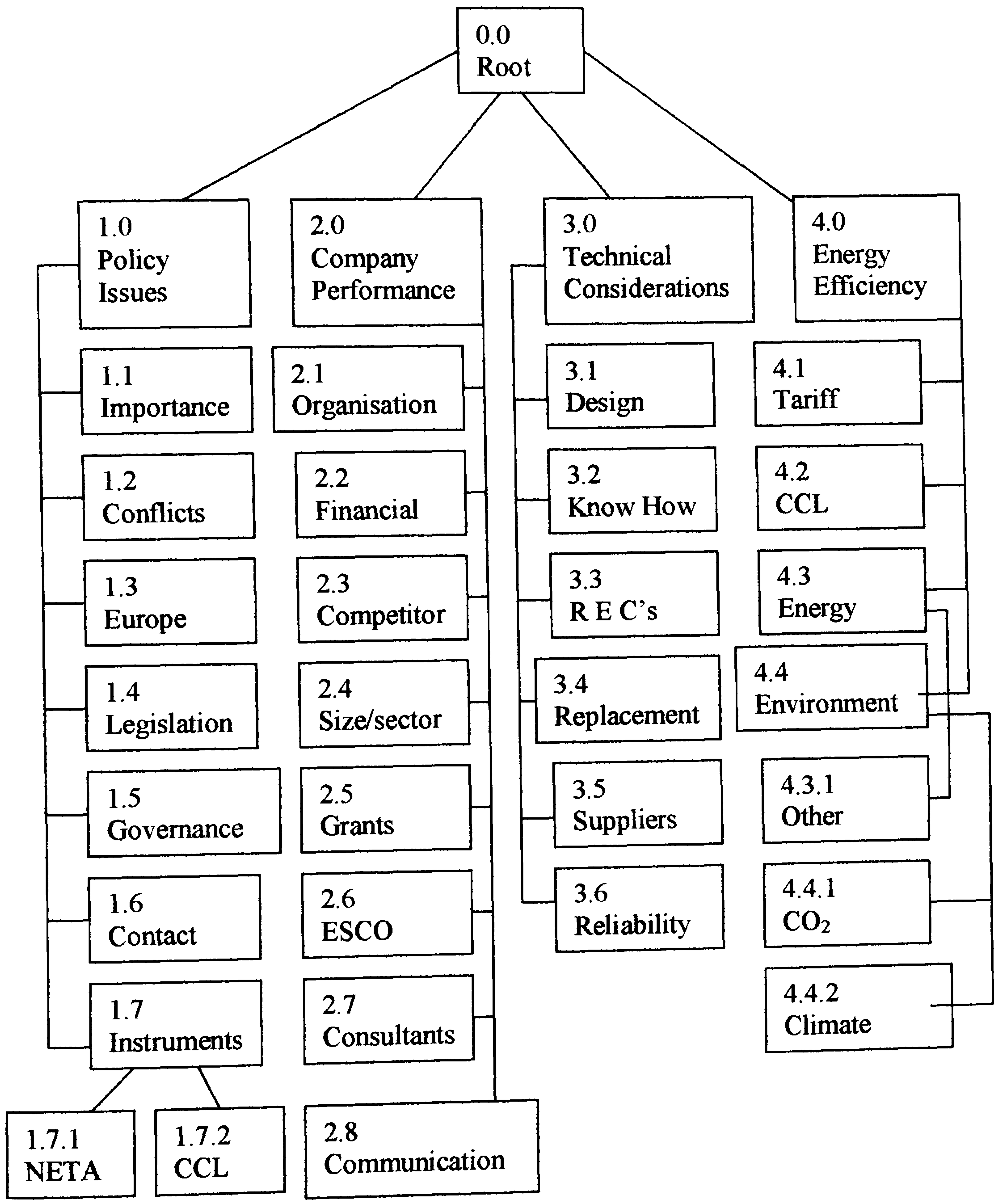


Table 6.4 Comparison of data obtained from semi-structured interviews

KEY ISSUES	AGREE	DISAGREE	NO COMMENT
There are potentially new and additional Government instruments that can be used to increase the use of CHP in SMEs.	DEFRA Consultant Ofgem REA	CHPA DTI	Thames Utilities
The New Electricity Trading Arrangements (NETA) will have a negative impact on CHP installations in SMEs.	DEFRA Consultant Thames Utilities	CHPA REA	DTI
The CHP quality assurance programme would be a key factor for new CHP projects.	DTI CHPA DEFRA	Ofgem Consultant Thames Utilities	REA
The information provided by the Government on CHP is easily accessible and understood.	DTI	CHPA DEFRA Consultant Ofgem	Thames Utilities REA
The market would not be skewed in favour of CHP after the Climate Change Levy and other fiscal measures are introduced.	CHPA DEFRA REA	Ofgem Consultant	DTI Thames Utilities
Financial Grants and third party funding are essential factors for CHP schemes.	CHPA DEFRA DTI Thames Utilities	Consultant REA	Ofgem
New equipment should not be installed where CHP could provide the same service, e.g. standby generators.	DEFRA Consultant Ofgem REA	CHPA	DTI Thames Utilities
The low energy prices over the past five years have hindered the development of CHP schemes.	CHPA DEFRA Consultant	DTI Thames Utilities Ofgem	REA
The consideration for designing a CHP scheme should not include energy efficiency measures.	DEFRA Consultant REA	CHPA DTI Thames Utilities	Ofgem

The responses noted in Table 6.4 are further set out as a collection of themes in a format relevant to the research objectives:

- Information delivery and communication strategies for SMEs.
- CO_2 reduction - the message for encouraging the use of CHP by SMEs
- The appropriateness or otherwise of fiscal incentives for SMEs.
- Fuel price sensitivity for CHP schemes.
- The need for developing the sustainable learning capacity of SMEs.
- The role of the Local Authority as the intermediary for marketing CHP.
- The availability of grants and third party finance mechanisms for CHP.
- The requirement for independent assessment for CHP by SMEs.
- Business indicators of benefits, finance, energy, environmental.
- Limitations of recent Government policy initiatives for CHP.
- The role of the manufacturer or ESCO in improving the plant reliability.
- The market driver for business, energy efficiency or CO_2 reduction.
- Governance of CHP – changes required in the regulatory framework.
- Regulatory policies for the technical standards of network connections.

These themes, some in the nature of questions identified the main facets that any new framework for encouraging the use of CHP by SMEs should seek to address. It was clear however that for any new framework to be relevant to businesses it should include markers and limits for the scope of CHP use as clearly not all SMEs would be suitable for using CHP systems. The information gained from the interviews were used to develop subsequent arguments relating to the 1st and 3rd research objectives, in Chapter 7.

6.5 Analysis of the data collected from the survey questionnaire.

As with the start of previous data collection exercises, the themes outlined earlier were used to prepare a questionnaire for surveying the opinions of existing small scale CHP operators. The format of survey questionnaire was adapted from one used by Christie, et al, (1995). The intention of the survey was to test these emerging themes with existing SMEs operating CHP plants and to identify whether their responses were in line or added further information to those already obtained from the three previous data collection methods. This survey was also considered important, as it would also afford robustness of the conclusions resulting of the research study. It also allowed for identification of quantitative data for any new decision support tool for the installation of CHP. Table 6.5 presents a summary of the numbers returned in each business category that was surveyed. This table is an indication of the effectiveness of the method of data collection in each category. The responses were analysed using the SPSS software. The coding structure for analysing the responses with SPSS is provided in Appendix 6.1.

Table 6.5: Summary of Survey Questionnaire Returns

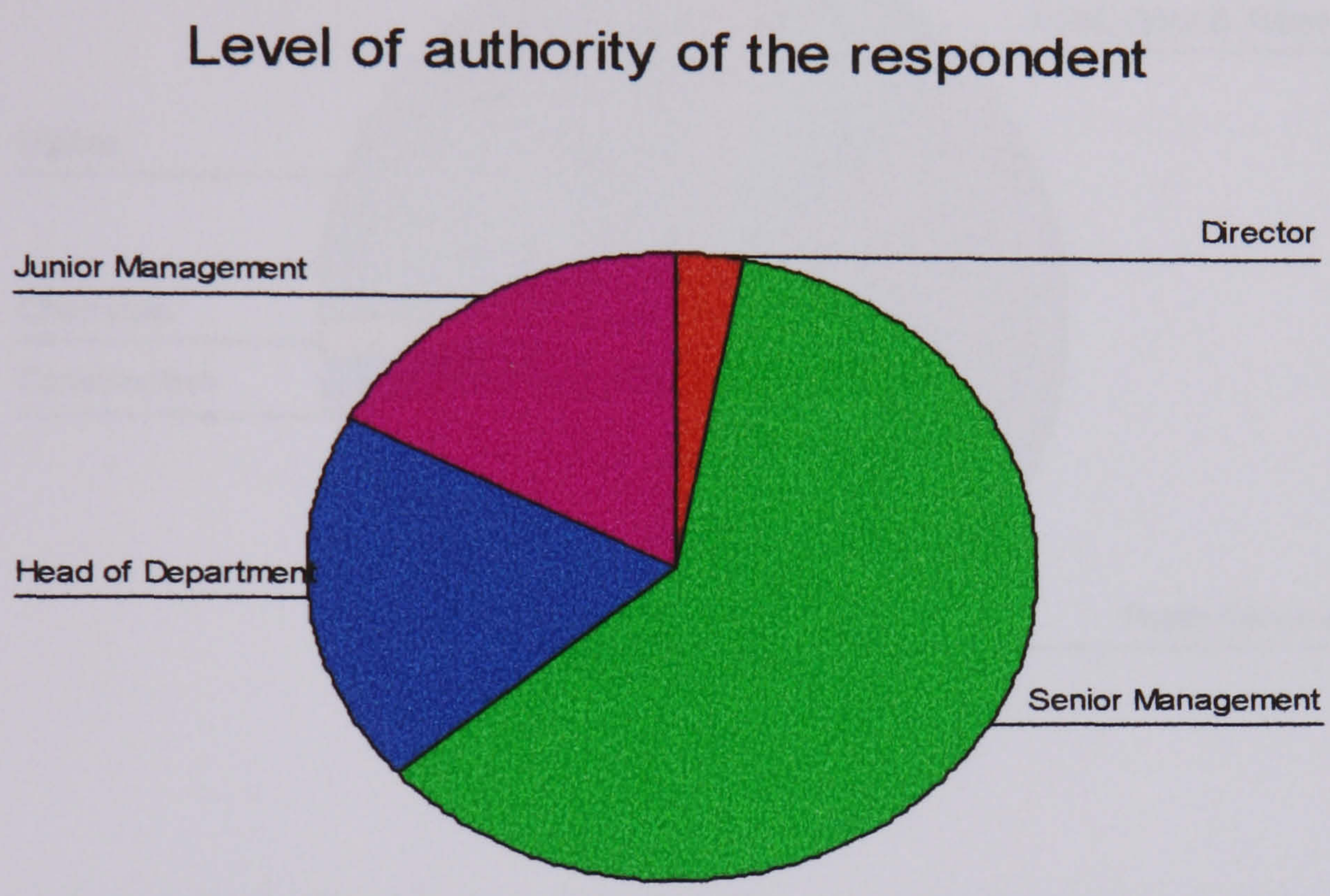
Business Sector	Number Surveyed	Number Returned	% Returned
Hotels	39	16	41
Offices	13	7	54
Sewerage	21	11	52
Leisure Services	241	60	25
Other industries	17	5	29
Total	**331**	**99**	**30**

The survey questionnaire was set out in three parts. The first part sought to identify the characteristics of the organisation and the profile of the responsible person. This was carried out to ascertain a target in the SME and the context of future CHP promotion to SMEs. Starting with an examination of the profile of the responsible SME manager, the first question related to the job function of the respondent in order to identify the scope for decision – making in the operating organisation. A variety of titles were offered by the respondents mostly referring to technical personnel. There were three predominant titles; Energy Manager (10), Chief Engineer (12), Facilities Manager (11). The conclusion from the response this question is that the CHP system is likely to be the responsibility of technical personnel. They would be the first point of contact. It may also indicate the importance of the technical performance or imperative in the decision making process for the use of CHP.

Analysing the results for the 2nd and 3rd questions, Chart 6.12 shows that the responsible person for a CHP system is also likely (79%) to be from the Senior Management, probably a head of Department. Whilst this level of staff does not suggest CHP competence, it does envisage the capacity to understand the technical principles and basic factors underlying CHP systems. The inference from this analysis is that from a marketing perspective and that of developing a framework, the target audience should be the Head of the Technical Department as the champion.

It also suggests that the decision making criteria would not only be based on technical performance but also on the use of management information systems such as financial performance. Any CHP promotion should therefore include both technical and financial performance indicators.

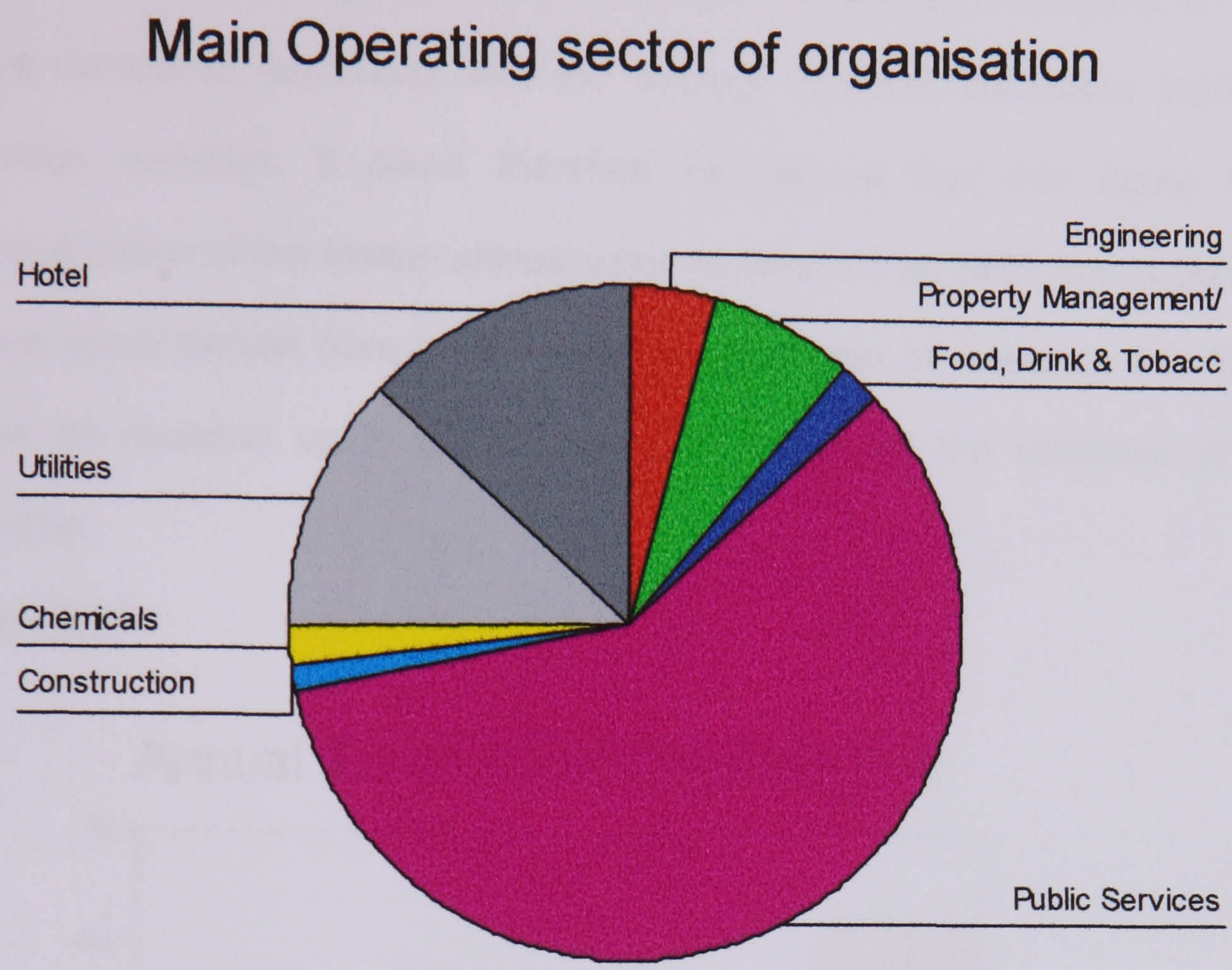
Chart 6.12



Of the respondents to question 4 (Chart 6.13) 54% were ex public services leisure enterprises[37]. The remaining 46% included other Leisure Enterprises (9%) and businesses such as Manufacturing, Hotels, and Offices. As 63% of the total respondents, were leisure service organisations, a view was taken that any analysis of the data as a response to this question would present an undue bias towards the views of leisure services enterprises.

[37] As a result of Compulsory Competitive Tendering, leisure centres were set up as semi-autonomous small businesses by local authorities and do therefore fit into the definition of an SME in this Thesis

Chart 6.13

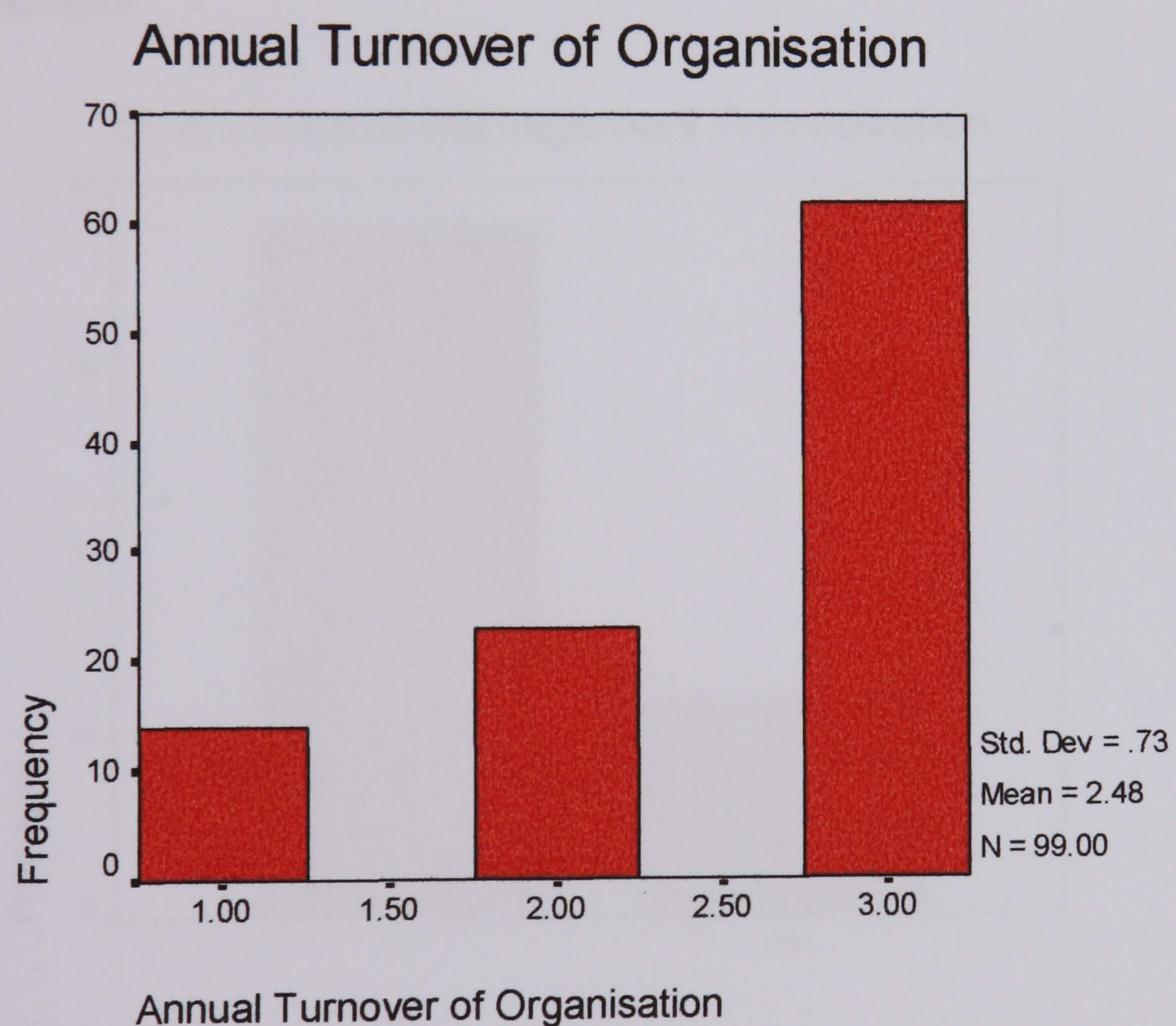


It was therefore decided to use only the data from the 9% non ex public sector leisure enterprises, along with the data collected from non leisure services SMEs to identify the mean lowest turnover of SMEs using CHP. This group totalled 46 organisations. This iteration was deemed justifiable as any figure obtained would be considered a "deminimis" level of turnover for the installation of a CHP system and would therefore necessarily allow for the higher turnover SMEs.

A breakdown of the 46 returns showed that, 14% have an annual turnover of about £1m, 9% of over £5m and 23 % of about £2m. For analytical purposes, the statistical average (mean) turnover of this sub group could be represented as; 14 x 1 + 23 x 2 + 9 x 5 = 105: 105/46 = £2.3m

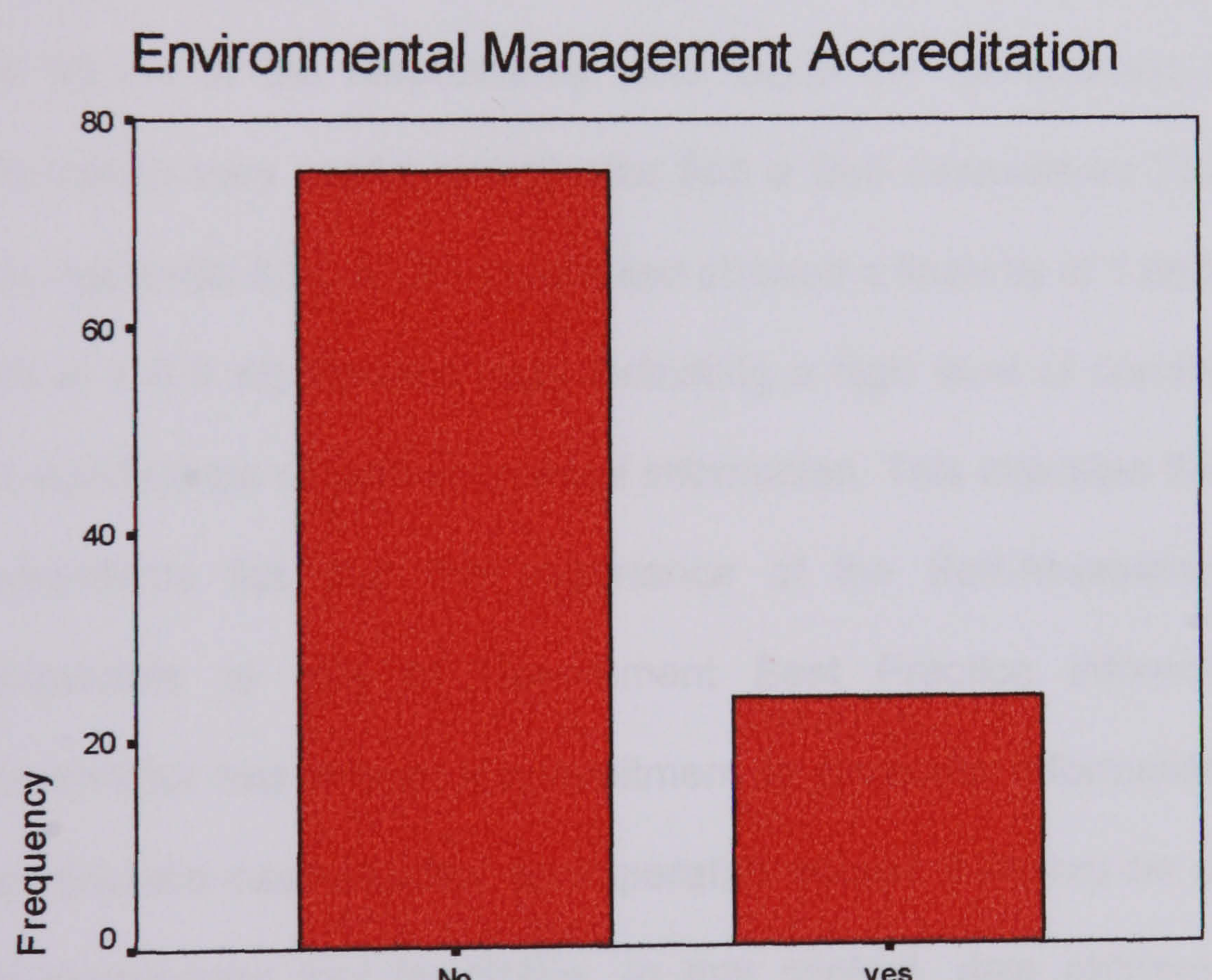
Analysing the response to question 6, (again using all the responses) a mean of 2.48 was derived by the statistical analysis as shown in Chart 6.14. This figure compares favourably with the average turnover calculated from the previous question. It could therefore be argued that this figure is a representation of the lowest annual turnover level for an SME that is likely to derive some benefit from a CHP system. For ease of reference this figure could be rounded up to £2.5m, taking into account the inference of the question.

Chart 6.14



The responses to questions 7 and 8 showed that almost all of the respondents (99%), used their own building to operate a CHP system which was located in an individual building (97%). This would imply that CHP systems are likely to be promoted for use on own sites, a factor that may also be useful to ESCOs when considering contract risks. In question 9, of the respondents that did not have an accredited environmental management system, 75% indicated that an environmental imperative was not a key driver for CHP in SMEs (Chart 6.15). This would suggest that the Government's drive to reduce CO_2 would be a message lost on SMEs except where there are other facets to that message. The notion of a senior SME manager being motivated solely by the need to improve environmental management through the use of CHP (as envisaged by the Government) is not supported by the research data.

Chart 6.15



The second part of the survey questionnaire related to the qualitative drivers for CHP use. In attempting to understand the communication framework for CHP in SMEs, an assessment of SME attitudes to primers for CHP showed a

74% indication of finding the use of a self-assessment tool for CHP as very useful. A comparison of the data collected is shown in Table 6.6

Table 6.6; Useful sources of information for developing CHP schemes

Frequency of use	Government Best Practice Information	Self Assessment Tool	Conferences and Seminars	Consultants	Industry Associations
Very	80	74	33	38	25
Not very	6	5	37	20	17
None	5	3	10	18	27
No reply	8	14	19	23	29

Cross-tabulating the responses between the two highest responses showed that 94.2% of the respondents, who found the Government Best Practice Information very useful, would also find a Self-Assessment Tool very useful (see Appendix 6.2). A Chi square test showed a linearity of 1 between the data sets at a 0.9 significance level indicating a high level of correlation between the significance of both sources of information. This indicates that in the main, respondents felt that the importance of the Self-Assessment Tool was comparable to that of Government Best Practice information. As the Government has shown a commitment to providing information through the best practice case studies, an imperative should therefore be an appropriate self-assessment tool for SMEs. In that context, data obtained on the key drivers from Question 11, summarised in Table 6.7 which follows, becomes relevant.

Table 6.7: Key drivers for CHP use in SMEs

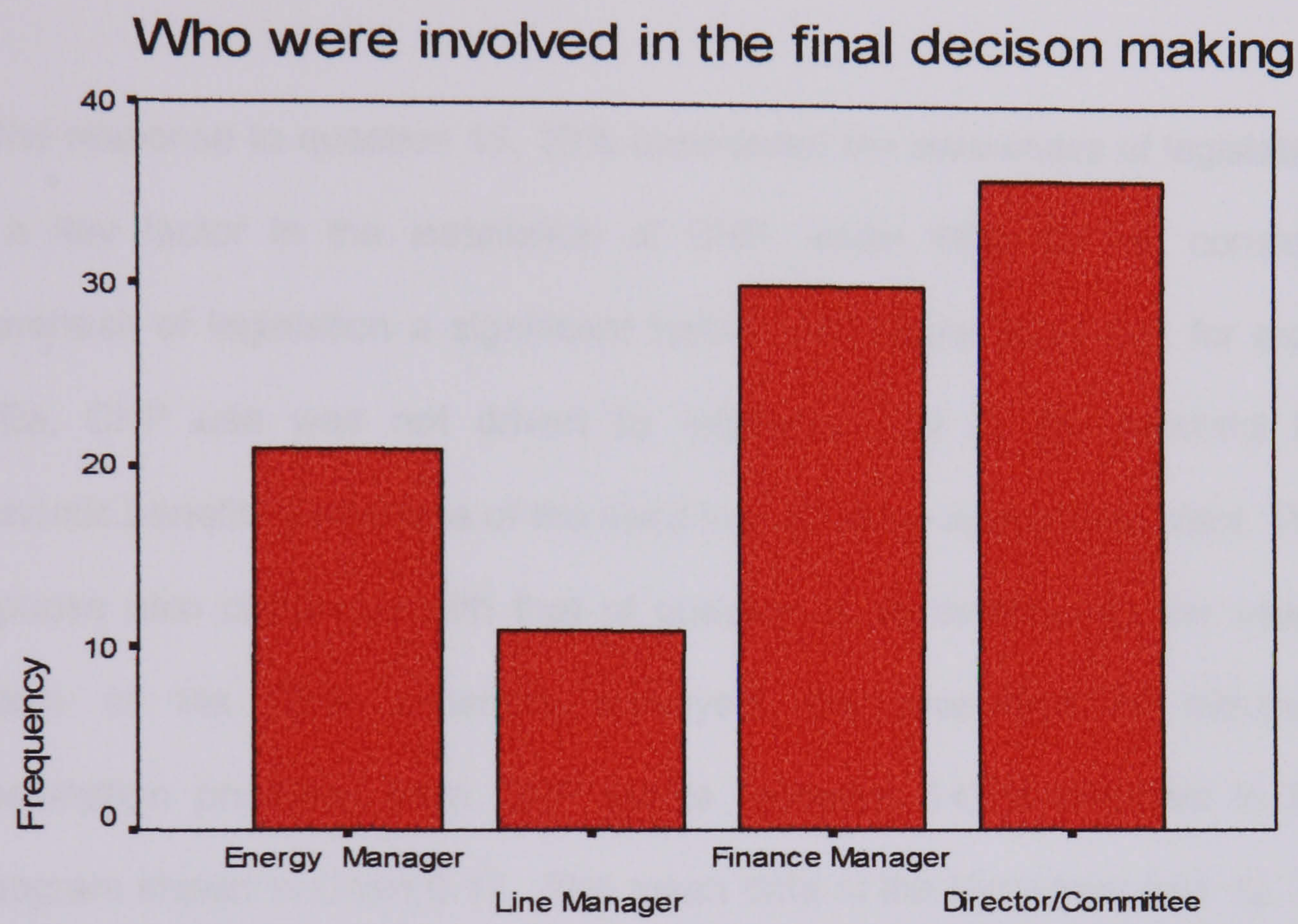
	Primary Driver	Secondary Driver	Non Driver
Economic Benefits	81%	11%	8%
Plant Replacement	13%	34%	53%
Financial assistance	10%	25%	65%
External Consultants	3%	9%	82%

The primary driver for installing CHP, as identified in the table, was the economic benefit it offered. Plant replacement was considered to be the second most important driver. It also features as the most important secondary driver for CHP in SMEs. As a result, the data analysed in Table 6.7, show that SMEs who are driven by plant replacement would only do so under the primacy of pre-determined economic benefits. This is where a link with the use of an ESCO could be made. This link would suggest that a CHP system which offers technical benefits, within a predetermined financing regime should be a marketing approach.

The aversion of cash flow constraints and utility price movements would then be managed within a framework set up to encourage CHP investment. Such an approach could be represented in the form of a new policy framework for CHP, incorporating a decision support model in the form of a Self-Assessment Tool. The Tool should also be able to accommodate options appraisal mechanisms that compare the economic, technical and environmental benefits of alternate plant replacement, in conjunction with CHP.

The analysis of the results from question 12, Chart 6.16, also indicates that the decision for installing a CHP system is significantly influenced by the Finance Manager and or the Finance Director.

Chart 6.16



This result, when compared to that of question 2, indicates the corporate nature of the decision making process and in particular the important role of the finance function in the SME decision-making process for CHP. Any new decision framework should not therefore focus entirely on the technical aspects of the CHP system but also should seek to address the finance function within the organisation. Decision indicators may therefore be expressed in three levels; energy performance, environmental performance, financial performance. This would also require a strategic alliance with other regional economic support framework such as the European Structural funds.

The role envisaged by the Government for devolved Assemblies or being carried out by Regional Development Agencies are practical examples of the scope for such a supportive framework. Integrating the growth of CHP use by SMEs within a spatial developmental framework is further examined in Section 7.5.

Of the response to question 13, 30% considered the awareness of legislation as a key factor in the installation of CHP, whilst 68% did not consider awareness of legislation a significant factor. This would imply that for most SMEs, CHP use was not driven by legislation but by the potential for economic benefits at the time of the need to replace an appropriate plant. This response also correlates with that of question 9. In determining the usage pattern of the CHP schemes surveyed, the proportion of electrical consumption produced from CHP plants (question 14) is depicted in the Histogram shown in Chart 6.17. The mean data of the Histogram was 42. By plotting a normal curve, an indication is provided of the general applicability of this average data to other similar CHP users.

The data collected from the responses to question 15, is also shown as a Histogram in Chart 6.18, with an indication of a tailed (the standard error of Skewness is 0.257) normal curve within the histogram. It indicates that for 91% of the respondents (88 out of 97 respondents), the CHP system could not be operated for about 14.6% of the planned use period due to breakdowns.

These datasets could therefore be used as typical values for CHP projects in the development of a new decision support tool. The justification for using these datasets is based on them being derived from the statistical analyses of the normal curve produced from the data collected. Detailed information relating to the principles underlying the statistical analyses is provided in Appendix 5.4.

Chart 6.17

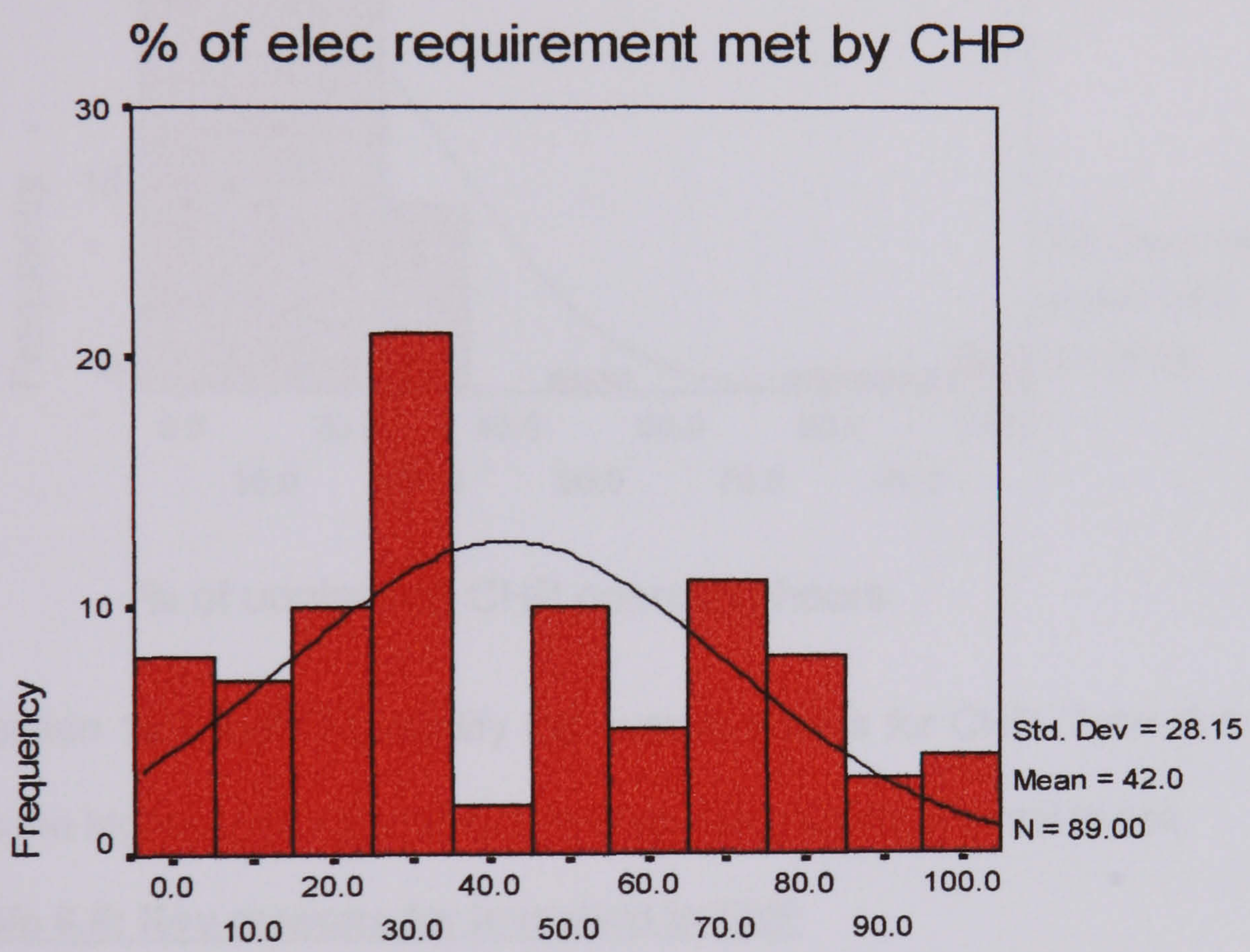
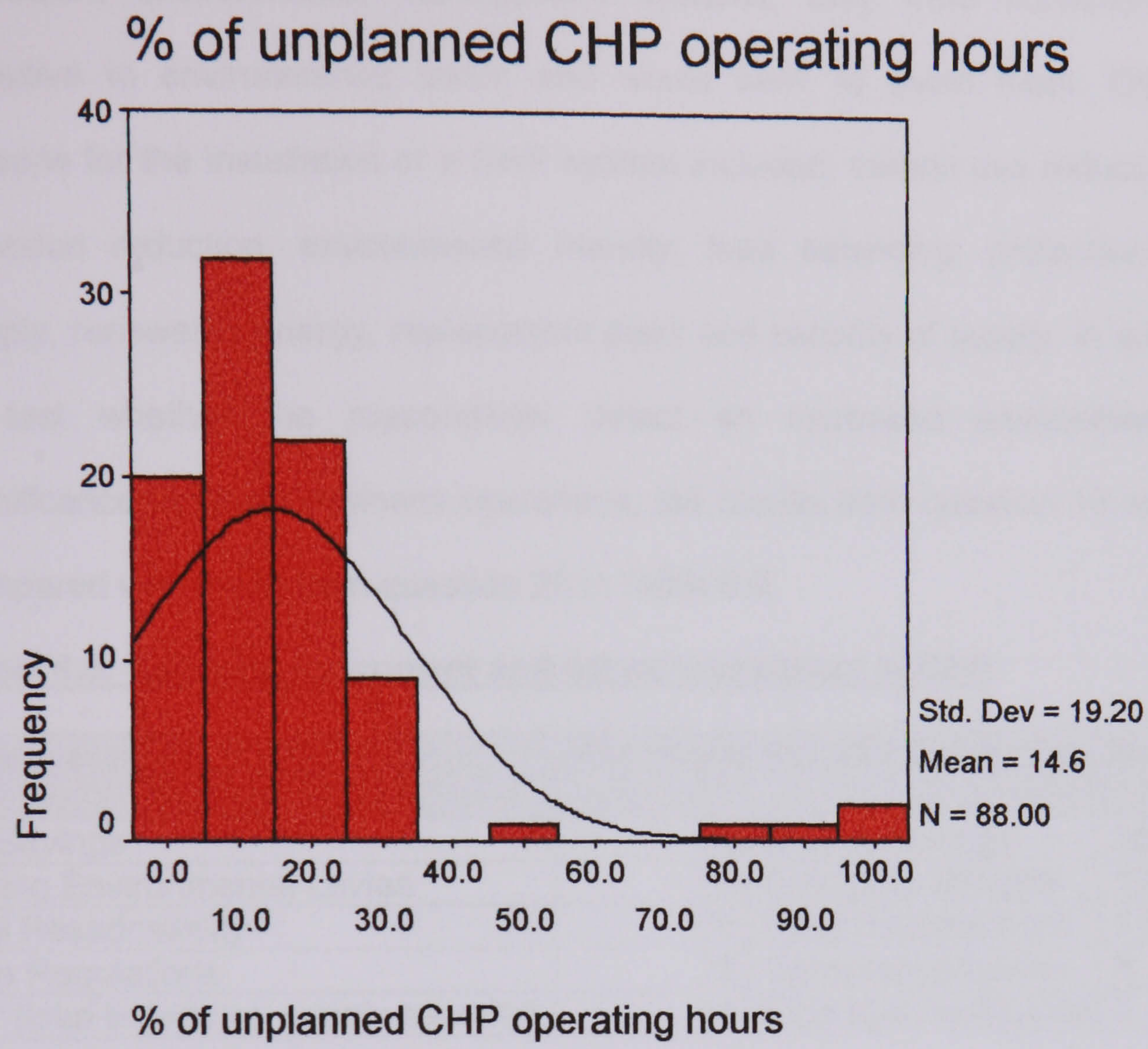


Chart 6.18: Percentage of unplanned CHP operating hours



Question 16 sought to identify the current drivers for CHP. Table 6.8 shows that the highest response was that of avoiding environmental levies.

Table 6.8: Key reasons for Investing in CHP

Frequency of Level of Importance	Avoiding Environmental Levies	Anticipating Future Regulations	Corporate Social Responsibility	Cost Savings Greater Responsibility
Very	58	36	35	35
Quite	30	36	51	51
Not	4	9	5	5
No Reply	7	18	9	9

This suggests that although 75% of the respondents (Chart 6.15) do not have accredited environmental management systems, they were nonetheless sensitive to environmental levies and would seek to avoid them. Other reasons for the installation of a CHP system included; carbon use reduction, emission reduction, environmental friendly, load balancing, protection of supply, renewable energy, replacement plant and security of supply. In order to test whether the respondents detect an increased environmental significance in future business operations, the results from question 16 were compared with those from question 23 in Table 6.9.

Table 6.9: Reasons for current and future investment in CHP

Current reason	Response	Future reason	Response
Cost Savings	94	Energy Savings	36
Avoiding Environmental Levies	88	Economic Benefits	19
Social Responsibility	86	Plant Replacement	11
Future Regulations	72	Compliance/Levies	8
Other (load balancing, supply security)	14	Financial Assistance	2

The level of response to current avoidance of levies could have been predicted, as the survey was conducted about the time of the introduction of the Climate Change Levy in June 2001. The response to the future reason for investing in CHP is perhaps more interesting, as it indicates that in the future, the Climate Change Levy may not be a driver for CHP. It is likely to be absorbed into mainstream business costs and would no longer be regarded as an environmental management charge.

Energy savings and economic benefits continue to rank high in the responses with energy savings in the context of CHP being attributed to plant replacement. There is therefore a consistence of technical and economic benefits as the two key factors directly driving CHP use by SMEs. The high score by Social Responsibility as a factor for CHP use could be interpreted as embracing the concept of Corporate Social Reporting which is gaining prominence in the EC. This would also be an indication of the potential future attraction of CHP to be promoted at a time of plant replacement.

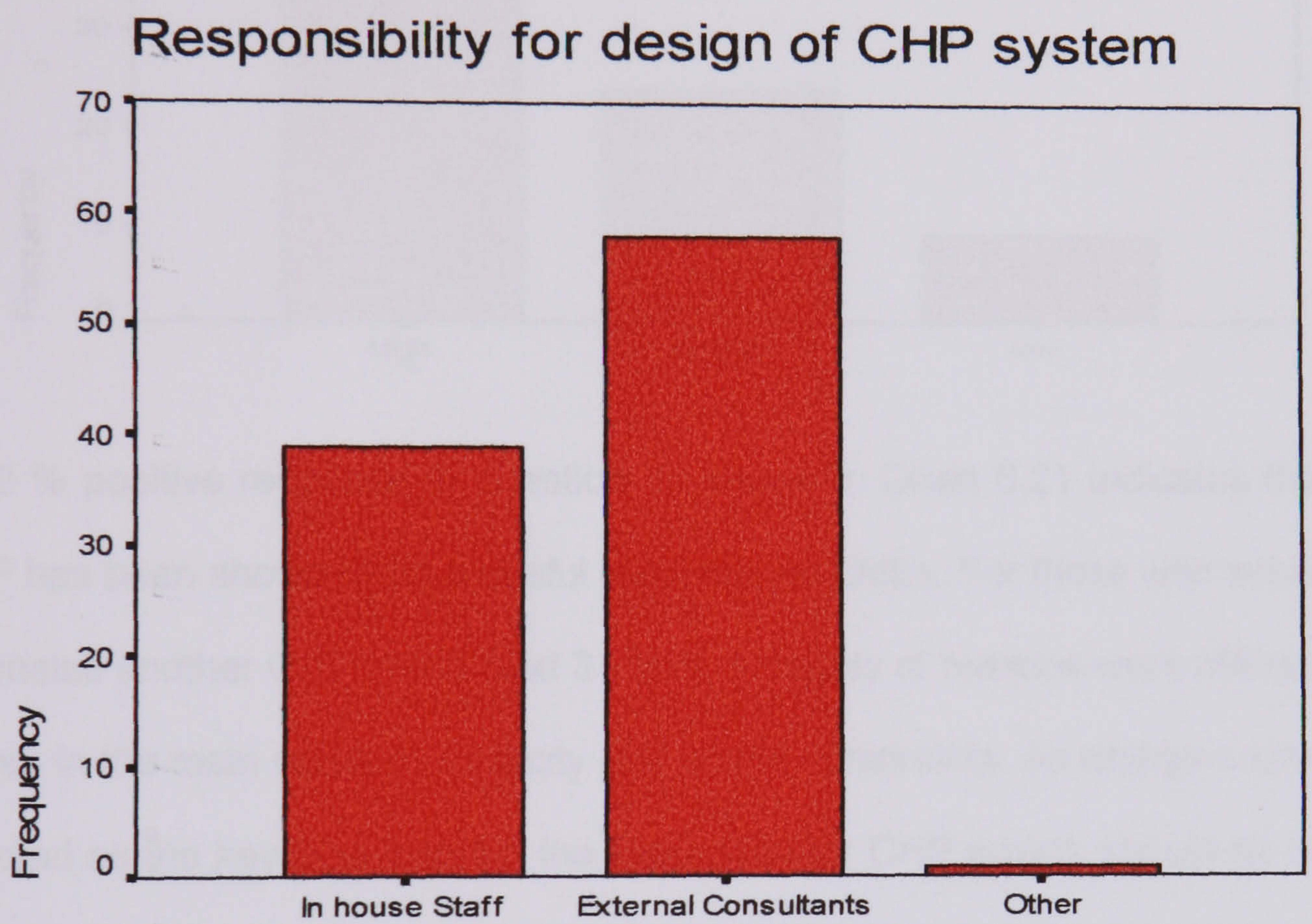
The results from question 17 showed that 58% of the CHP projects (Chart 6.19) were deigned by external consultants and 39% by internal staff. As the response to the survey question 18, "Was the CHP installation carried out as part of larger project?" showed that the majority of CHP schemes (75%) were carried out as part of a larger project, it is inferred that those schemes designed by consultants were the larger schemes.

Where consultants were used for the design of the scheme (61%), 51% of those schemes were installed by manufacturers as noted by the response to question 19 shown, in Table 6.10. This result again indicates the potential for encouraging the use of ESCO, as they would offer a single comprehensive service to design, finance and operate the CHP schemes in a more tax efficiently manner than many SMEs.

Table 6.10: Choice of Installers

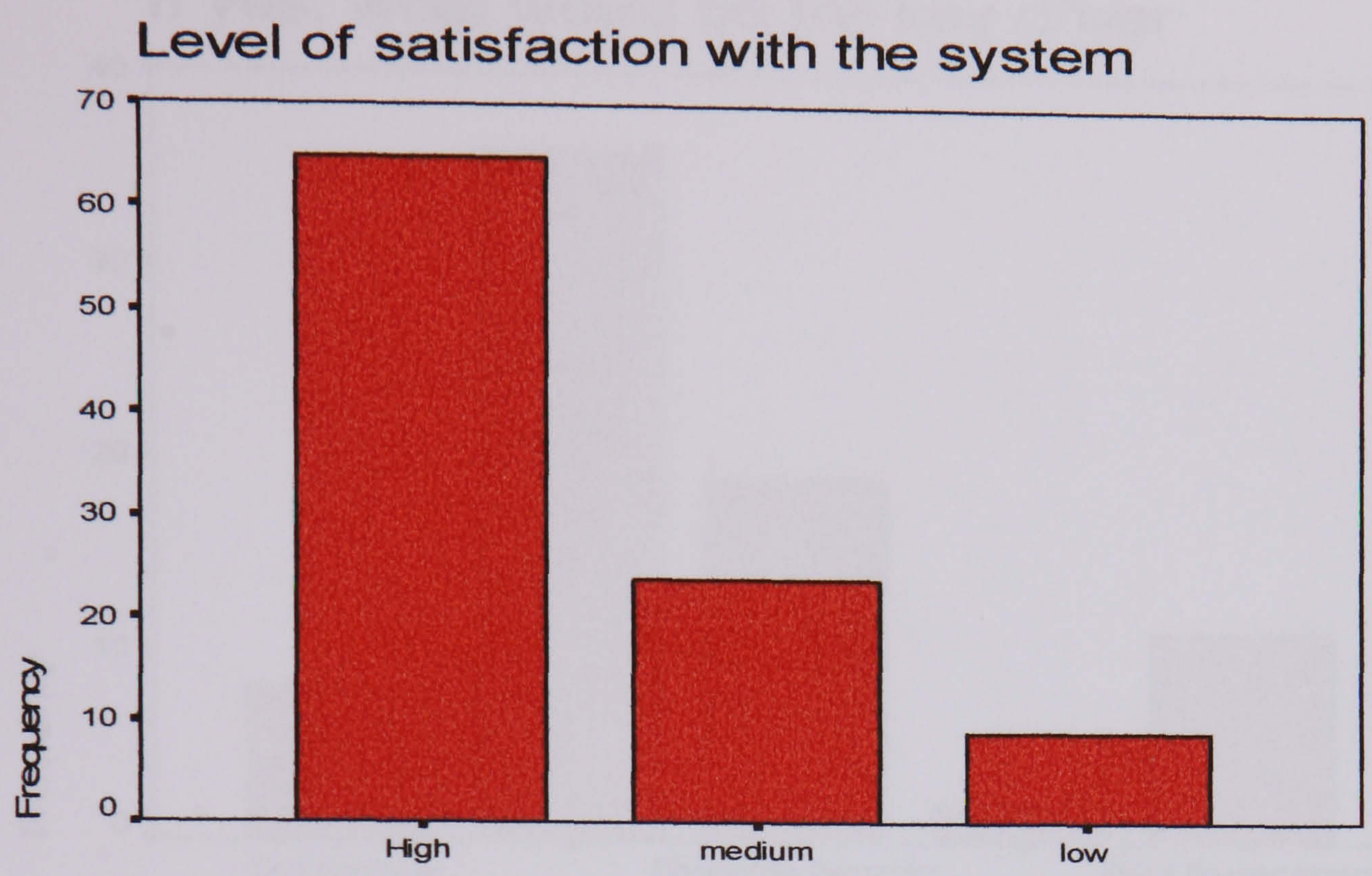
Designed by	Manufacturer Installed	Specialist Contractor Installed
In house staff	27%	10%
Consultants	51%	10%
Manufacturer	1%	
Do not Know	1	

Chart 6.19



Question 20 was designed to test for satisfaction with the operation of a CHP was designed to be an indication of a willingness to install another CHP system in the future leading to questions 21/22. The low response for a poor satisfaction level (Chart 6.20) with the CHP schemes (9%) should therefore be interpreted as an indication of a positive outlook for CHP use by SMEs.

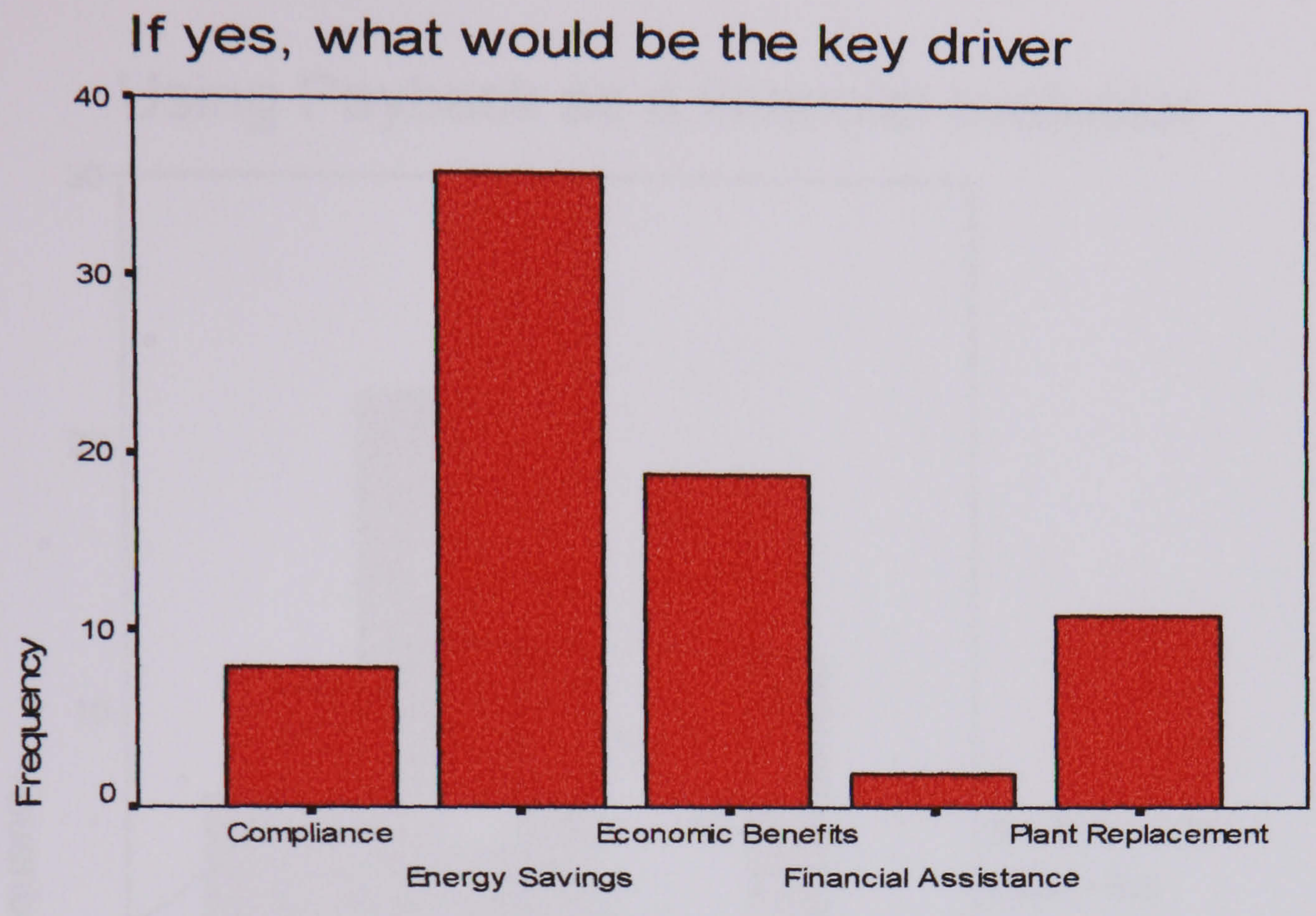
Chart 6.20



A 72 % positive response to question 21 shown in Chart 6.21 indicates that CHP has been shown to be a useful resource for SMEs. For those who would not install another CHP in the next 3 years, a variety of reasons were offered. These in the main relate to capacity and space constraints. As energy saving is noted as the key future driver, the focal point for CHP growth should be on SMEs wishing to replace new plant. These SMEs would be identified though manufacturers or Local Authority planning departments.

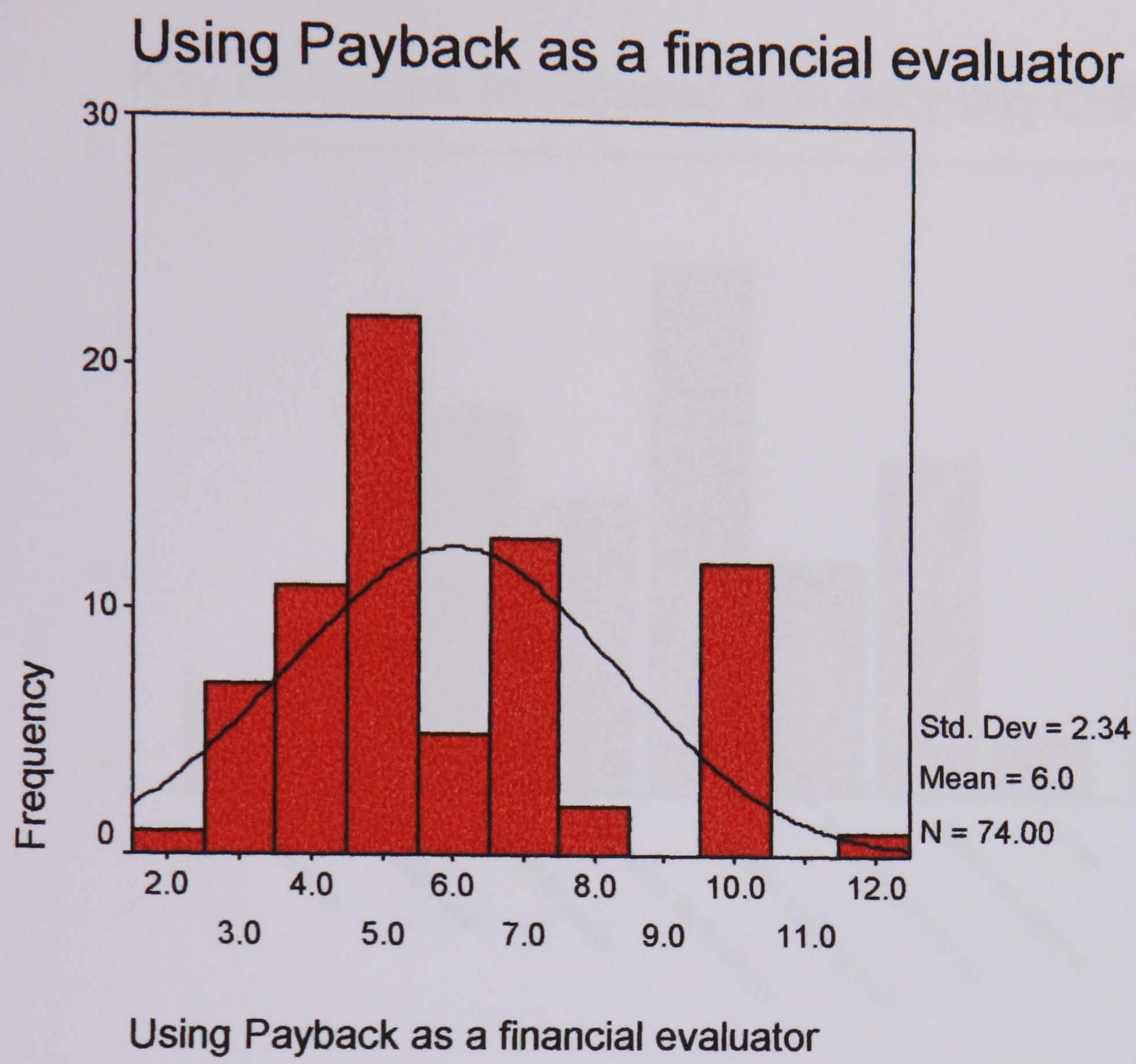
This analogy is further evidenced by the responses to question 24, which indicated that 51% of CHP schemes were third party funded and that 58% of the respondents noted the availability of financial assistance as significant, in question 25. Both results indicate the potential for promoting CHP to SMEs with the available third party funds, at a time of plant replacement.

Chart 6.21



Question 26 was set to identify the range of financial indicators used by SMEs and their target levels. The responses for payback for were analysed as a histogram in Chart 6.22, showing a normal curve and indicating a mean of a 6-year payback period. A normal curve would also suggest the generic use of this generic figure as a guide for analysing new CHP potential.

Chart 6.22



An analysis of responses, for the Internal Rate of Return[38] (IRR) suggests 12% as the mode. There were very few responses on the question of use of Net Present Value (NPV), for it to be considered meaningful within the context of the survey. Other responses for financial evaluation, referred to the use of an ESCO or third party financier for developing the CHP scheme. In response to question 27 the main difficulties associated with the development of CHP schemes are indicated in Chart 6.23. The lack of an independent decision making tool noted as the most significant element.

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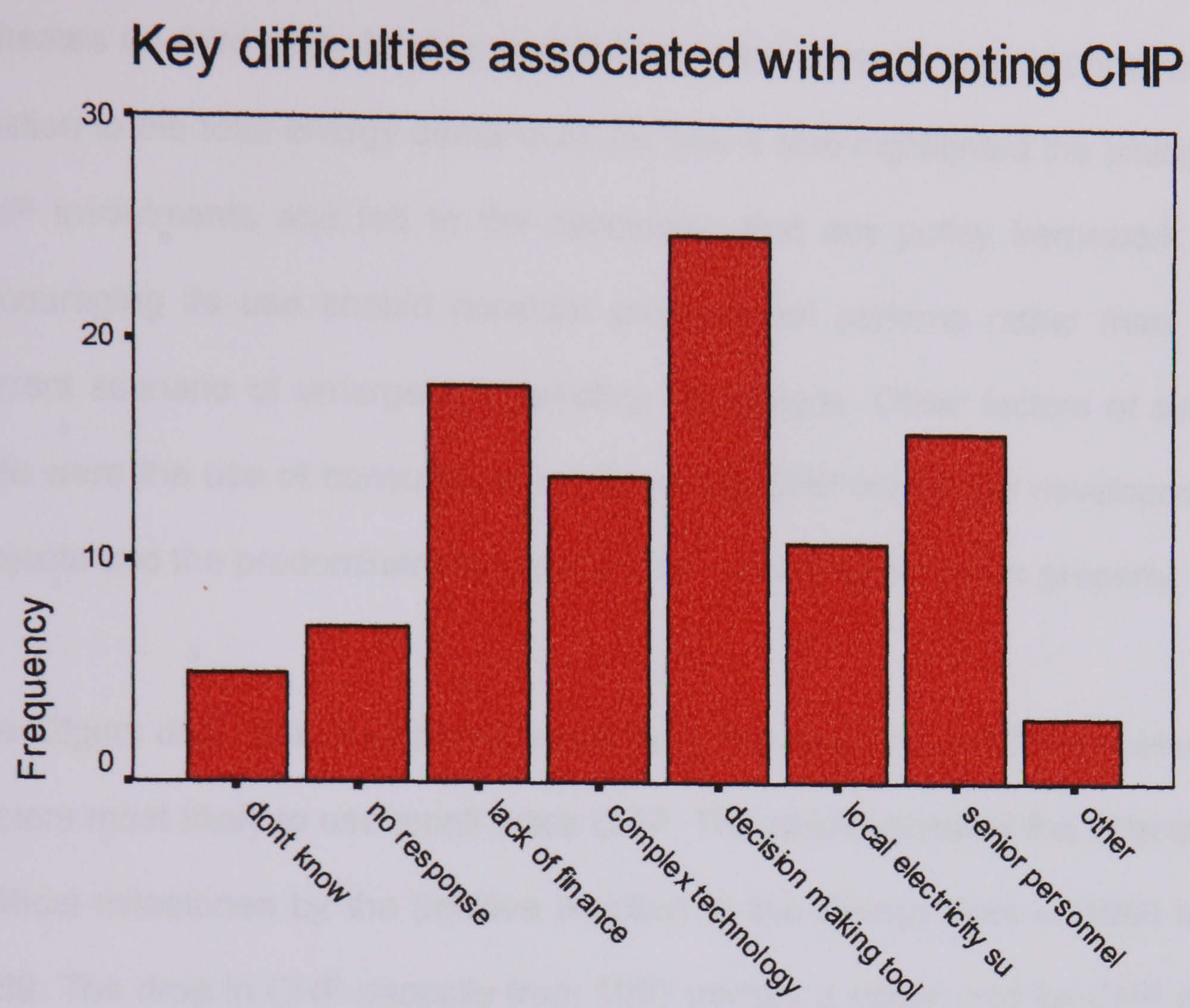
[38] The Internal Rate of Return is the discount rate, which when applied to project cash flows produces a Net Present Value of zero (Pike, R. & Neale, B., 1996)

Chart 6.23



This response reflects the importance of having an independent Decision-Support Tool that would be used by the SME manager to assess potential CHP schemes. The manager would then be in a position to explore a number of scenarios and if CHP is the preferred way forward would have a better chance at achieving an eventual installation as the commitment to the scheme would already have been established. The analysis of the survey data would be used in arguments relating to the 1st, 2nd and 3rd research objectives.

6.6 Conclusion

The review of the case studies identified the dependence of "successful" CHP schemes on third party funding and that installed capacity was not optimal in relation to the total energy demand of the site. It also highlighted the timing of CHP investments and led to the conclusion that any policy framework for encouraging its use should consider procurement patterns rather than the current scenario of untargeted marketing campaigns. Other factors of some note were the use of consultants, incorporating CHP into larger development projects and the predominant location of CHP schemes on owner property.

The Ofgem data analysis offered scope for a focus on the five SME business sectors most likely to use small scale CHP. The results showed the effects of political milestones by the positive reaction to the Energy Acts of 1983 and 1989. The drop in CHP capacity from 1997 mirrors a policy void for CHP and in particular the development of NETA. The results also point out the poor environmental efficiency of the installed systems as electrical capacity was the driving factor, the value of heat being minimised. There was no correlation between the level of finance charges and CHP capacity which implied the dominance of plant replacement in the decision to install CHP, where grant assistance was available. The more significant factor however was spark spread, a function of relative utility values, noting that above a spark spread value of 3.5, CHP capacity reduces. It could therefore be argued that the current Government policy for CHP use in the UK is ineffective as it is supply led and centred on grant availability for increasing electrical CHP capacity.

The themes developed from the semi-structured interviews, whilst confirming the previous conclusions, also noted the policy imperative for standardising technical support within a regulatory framework, such as that carried out by Local Authority planning departments. The nature of communicating the CHP message to SMEs, which is dominated by CO_2 reduction, also emerged as a strategy that was of limited value to SMEs.

Data collected from the survey questionnaire also confirmed the pre-eminence of plant replacement and financial assistance as the key demand led parameters for CHP use. The results showed that existing operators were happy with the CHP systems and would install additional capacity where space and finance were not constraints. The results also provided a number of generic numbers identified as statistical means from normal curves that could be used in developing decision support indicators within a self assessment tool for future CHP project appraisals.

The results therefore demonstrate the need for a more holistic approach to the promotion and use of CHP by SMEs. This implies the development of a new sustainable policy framework that would include the use of CHP, such that an SME would readily be able to identify its position in relation to the key drivers for CHP. A new strategy is therefore required, which centres on targeting demand management parameters such as plant replacement, independent project assessment, financial support and a targeted environmental value for the heat produced.

Chapter 7

Discussion of Results

7.1 Introduction

The comparison between the results of the semi-structured interviews was noted in Section 6.3. This comparison was made in order to identify differences in policy directions between Government departments. In particular Section 6.3 identifies the key issues derived from the analysis of the semi-structured interviews. These issues could also be interpreted to be the emerging themes to be addressed in any new Governance framework designed to encourage the increased use of CHP.

In a further attempt to relate the emerging issues to the research objectives, they are further condensed into 4 broad categories:

1. The targeting of those drivers that stimulate demand within SMEs.
2. The CHP message within the context of energy efficiency
3. Financial assistance for CHP project development
4. Using a spatial regulatory framework for technical standardisation

This Chapter discusses the implications of the results of the research based on these 4 categories and relates them to the aims and objectives of the research detailed in Section 1.7.

7.2 Targeting the key drivers for CHP within SMEs.

Government policy initiatives have centred on the macro level of allowing fiscal measures to encourage the use of CHP in SMEs. The climate change package of measures and the introduction of NETA are all examples of these. The research however point out that SMEs have used CHP systems where they have a specific demand and where there is financial assistance. The effect of spark spread and the limitations of site ownership are all factors in the determination to use CHP.

Government policies therefore need to change such that if CHP use in SMEs is to be encouraged then new mechanisms need to be found whereby SMEs could be particularly targeted with the profile of plant replacement, own location, suitable energy demand. In particular, CHP should be offered as a technology that has a broader appeal than the replacement of imported electricity with a greater value being placed on heat output. One way of doing this would be to consider the use of CHP as a "de facto" boiler or generator capacity at a time of their individual replacements and a consideration of a "CHP heat" Obligation. As Local Authority building control approval is required for new commercial plant capacity, all such applications should be made to consider as a first option the use of CHP.

Another consideration is the importance of spark spread to CHP. The notion of a limiting spark spread value (Section 6.2.2) would suggest a utility price management framework for CHP thereby improving its economic performance.

DTI_1 (90-93) commented that CHP should be taking an independent economic position in the electricity market: "*I think we will be in a world where you will have to say for better generation, you will have to say ok, rules have changed somewhat, it has to be easier or cheaper to connect, but really then, CHP would have to live on its own economics*".

Such a view does not factor in the additional environmental benefits of the heat that CHP produces but is not acknowledged by the SMEs as they would only use CHP when an electrical plant is to be replaced and where adequate financial support is available. In such a scenario market forces becomes inefficient and encourages the argument for a new fiscal instrument.

The suggestion that the domestic target of reducing CO_2 emissions to 1990 levels by 2010, is unlikely to be reached by the PIU (2002) and ILEX (2003), should encourage the Government to take further powers under the Utilities Act, 2001. Such powers may include the obligation for Utility Companies to purchase electricity produced from CHP plants at a specified price, designed to encourage the CHP industry as a CHP obligation. The CHP Obligation should mirror the limiting value of spark spread and the value of the heat output, thereby ensuring that the conditions for CHP used are always normalised with respect to its own economic parameters. Should a CHP Obligation be introduced as an extension of the Utility Act (2001), it is could operate in a similar way to the "Renewables Obligation" (CHPA, 2002a), which maintains the cost effectiveness of renewable energy schemes.

7.3 The CHP message within the context of energy efficiency

When asked, "Which of these sources of information would be most useful to you?" 80% of the respondents to the questionnaire survey, noted the Government's Best Practice Information Programme. The effectiveness of this programme would therefore be a barometer of the perceived benefits of this communication strategy. The following extracts from the semi-structured interview transcripts provide an indication of how the effectiveness of the Government's communication with business was perceived by the respondents.

$CHPA_1$ (108) stated, "You can argue that these fiscal incentives are not needed. What is needed is clear policy for the CHP sector". *$DEFRA_1$ (14) stated,* "The Government's CHP communication channels are through mail shots, seminars and corporate commitment campaigns". *DTI_1 (26-32) notes,* "*The EEBPp publishes energy consumption guides, that survey energy use in a particular sector. This allows companies to bench mark their existing performance against similar organisations. Hence a company can establish if their energy consumption is higher than sector norms. This form of benchmarking has been carried out in a number of sectors including sectors with a significant number of SMEs such as small breweries, craft bakeries and laundries. Lists of energy consumption guides are available via this web page:* http://www.energy-efficiency.gov.uk/info/pubs/DEFRA3/frames/index_2.cfm.

Look under publication type then Energy Consumption Guides. Any publication can be ordered through the environment and energy help line: 08800 586794". However, the CHP Expert Consultant (204-205), takes a slightly more cynical view on the Government's communication drive, noting, "*the real issue is because all of this is about communication. The problem of communication is not in SMEs. The problem of communication is in bloody Whitehall*".

The promotion of energy efficiency to SMEs has been reverted to the Action Energy Programme and is effected through financial support for project appraisal. A major concern expressed by industry experts about the Carbon Trust, is the perception of its pre-eminent concern with Emissions Trading, as opposed to Emissions Reduction, in the UK (I MechE, 2002). The UK emissions trading scheme is based on a commodity-type market with the commodity being the regulatory risk, not Greenhouse gas emissions (Bossley, L., 2002).

The International Energy Agency (IEA) in supporting the European Emissions Trading Scheme, which is based on selling Carbon Dioxide savings, notes that an effective international system for Carbon Trading will facilitate the significant contribution from CHP in fulfilling the Kyoto commitment for 2008-2012 (IEA, 2003). This argument is partly based on the potential for change of the current fuel mix for marginal electricity production in the UK. However current indications are that the scheme, to be started in 2005, would not include electricity produced from CHP plants (IEA, 2003:19).

This has prompted the IEA to further comment that "*the Emission Trading scheme will therefore constrain CHP schemes, without a means of crediting the full value of the environmental offsets by the heat and electricity from CHP projects*" (IEA, 2003:23). The reduction of CO_2 emissions being the intended consequence of the Emissions Trading Scheme, could in many ways be consistent with Energy Efficiency, such as with the use of CHP. However, a dominating commercial interest for Emissions Trading raises new questions, such as the Carbon Trust's ability to deliver the wider objects of the climate change programme for all business sectors, particularly SMEs.

One of those questions is the potential for conflict between the drive for energy efficiency, which produces emission reductions and the drive for emission reductions, which does not necessarily offer energy efficiency benefits. With Emissions Trading, a business that could sell its CO_2 emission reductions by fuel switching would not need to move towards the use of clean technologies such as CHP. This scenario would ultimately reduce the likelihood of CHP being used if extended to other international trading mechanisms such as the Clean Development mechanism (CDM[39]). The EUETS may not be all doom for the CHP industry as the IEA (2003:21) predicts increases in power prices of about 40% over a 5-year period. This is likely to happen over a period of fluctuating prices and uncertainty for CHP investors.

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[39]Clean Development Mechanism (CDM)-Project based schemes allowing Carbon Credits to be claimed for emissions in developing countries due to investment by developed countries (IEA, 2003)

If the message of CO_2 reduction is to be part of the strategic considerations of SMEs, then the role of the EEACs, with the imminent change of character to Regional Sustainable Energy Centres, should also change with respect to their signposting relationship. CHP use by SMEs could be promoted on the basis of a regional environmental strategy as it would fit in with their overall marketing strategy. The Sustainable Energy Centres would then approach the advice provision, not just as an exercise in giving advice, but more in terms of tangible deliverables, such as an examination of CHP planning requests to ascertain full environmental efficacy.

The demise of the pilot SMEEEAC support service originally envisaged as substitute to the former Energy Efficiency Best Practice programme (EEBPp), was in part due to its delivery structure which was supply led and not demand led. The removal of this local tier of energy advice support for SMEs has meant that the promotion and marketing of the CHP potential to SMEs is largely the responsibility of consultants, with no specific local or spatial context for their promotion. Government campaigns for CHP are therefore based on a national scale and therefore offer little relevance to SMEs in terms of stimulating their demand. National CHP campaigns, because they are supply driven are therefore ineffective in terms of stimulating CHP demand. Christie et al., (1995; 279), had arrived at a similar conclusion on the type of support to SMEs provided by the Government stating, *"there was a consensus that existing Government information campaigns on energy saving and waste minimisation were ineffective".*

A characteristic of the Carbon Trust's Action Energy programme is the top down approach to the provision of energy advice. Burgess et al., (1998: 1446), criticise this top-down communication approach to provide an advice service, referring to it as *"a deficit model that assumes that there is a deficit in public knowledge and understanding that needs to be filled by expert knowledge"*. They suggest a more participatory form of communication based on 'inclusionary argumentation[40]'. It could therefore be inferred, that the current Action Energy programme, would have a limited effect on CHP use by SMEs.

It could further be argued that the comments made by the interviewees (Table 6.10) in relation to the ineffective nature of Government CHP promotional policies would hold true when matched against the expectations of the respondents to the survey questionnaire i.e. the need for a Self Assessment Tool in addition to best practice information as the second highest-ranking response to question 10 in the survey. It points out the value of a twin track approach. The continued promotion of Government publications and the development of a Self-Assessment Tool on the basis of providing decision support as part of a new and integrated regional framework for CHP governance.

[40] This term implies public reasoning, which accepts the contributions of all members of a political community and recognises the range of ways they have of knowing, valuing and giving meaning.

7.4 Financing CHP use in Small & Medium Enterprises

The fiscal instruments in the climate change programme and the Carbon Trust's Action Energy Programme are indications of the Government's view of the importance of the energy performance of the SME sector. The policy instruments for encouraging energy efficiency by SMEs have however been only those announced by Chancellor of the Exchequer's in the 2000/2001/2002 budget statements. These relate to the climate change package (The Climate Change Levy, Enhanced Capital Allowances, Business Rates Reduction and the Renewable Energy Obligation) of measures. Subsequent budgets altered the way in which the measures were to be applied and offered further exemptions. The intention of this package of fiscal measures was to encourage the rational use of primary energy sources by businesses, especially SMEs.

The majority (5) of the interviewees in the research were of the view that the climate change package would be helpful to the CHP industry, as good quality CHP schemes were exempt from the Climate Change Levy and would therefore be attractive to business for avoiding levy charges. DTI_1 (12-13), noted "*these fiscal incentives would stimulate the CHP market and would offer significant environmental benefits*". $DETR_1$ (28), noted "*these policy instruments are expected to improve the economics of CHP by about 30%*".

Thames Utilities (42), who was responsible for the operation of 45 small scale CHP plants, had a slightly different view, suggesting that "*the Climate Change Levy, Business Rates Reduction & Enhanced Capital Allowances (ECA) were not going to play a significant factor in the decision process for CHP in SMEs. This is because Thames Utilities is cash rich and the fiscal incentives do not have a significant impact on its cash flow. The important factor is fuel costs and as such the CHP systems were useful in substituting methane gas from the sewers for natural gas, in the production of electricity for use in the water pumps*".

The $DETR_1$ (59) interview response confirms the Government's view of the significant impact that was expected of the Climate Change Levy and that "*other contemporary issues of low utility prices and energy conservation were transient in the drive to reduce CO_2 for which their primary instrument is CHP*".

It is clear however that after two years, the Climate Change Levy has not made any impact with respect to encouraging SMEs to increase their use of CHP. The research data weighed very heavily towards the availability of financial support either in the form of grants or third party funds from ESCOs. A number of factors should be considered in the context of financial support for SMEs. Firstly SMEs are by definition of a limited financial capacity. Secondly the research data suggests that CHP schemes are still considered as risky by businesses as noted in Section 6.5.

It is also clear from the results from the survey (questions 22 and 23), that the majority of the CHP schemes surveyed had received financial assistance. By linking the importance of financial assistance with technical support infers the need for supportive framework, one that creates an automatic link between potential ESCOs and SMEs within a region. This link should be within the scope of additional grant availability and technical support. In a sense it should be set up like the Energy Action Grant Agency's (EAGA) role for providing partial grant support and installation services to domestic households, for insulation and boiler replacements and other energy efficiency products.

It is easy to conclude that laudable as the intentions are for the Government's fiscal incentives for SMEs, they would not encourage the use of CHP in SMEs. These fiscal measures would be more attractive to SMEs if they were to acquire their CHP plant from a third party such as an ESCO. The measures could be useful to an ESCO of sufficient size to amalgamate its tax allowances through finance leasing mechanisms, so that the efficiencies of the ECA could be realised. Such an ESCO would then reflect this benefit in reduced charges to the end user including a reduction of energy use and CO_2 emissions.

7.5: Using spatial regulation for technical standardisation

The Kyoto environmental target is set for the whole Country and has not yet been identified in regional /Local Authority terms. It does not therefore feature in local sustainability plans as a pre-defined target, although some Regional Assemblies such as the GLA are now attempting to target CO_2 emissions within their boundaries (GLA, 2002, SDC, 2003). The Government's current strategy to develop policies on the basis of market sector, has led to a greater emphasis on larger businesses, than on the small business sector. Negotiated agreements and the Integrated Pollution Prevention and Control Regulations, are all examples of policy initiatives that have been directed at larger businesses. With the statement "*the Government does not have a specific policy for CHP in SMEs. The Government's key policy drive is to reduce CO_2*" $DEFRA_1$ (7- 9), there is an indication of a policy framework that would favour supply led initiatives, such as fuel switching to tackle climate change.

The promotion of CHP to SMEs on a national scale could only therefore be practically achieved through a CHP obligation as a management tool for utility prices. The implications of the Government using the extended powers in the Utility Act, 2001, to bring in a new CHP Obligation, may however encounter technical constraints in its implications for the electricity network, which is designed for a unidirectional flow of electricity. Any major increase in CHP capacity, entailing multi-directional flows, would require the laying of new networks. It would however offer significant benefits in giving a higher value to the heat output in offsetting CO_2 produced from other less efficient heat stations.

DTI_1 (5-6) further highlighted that the complexities of managing the network "*are based on responsibilities imposed by the deregulation of the Electricity Industry, in the Electricity Act (1989)*". In other words, further legislative changes would be required. The imposition of a CHP Obligation, without recourse to the legal responsibilities of the RECs, would have a detrimental effect on the financial position of RECs, particularly in the current low electricity price era.

The solution to this constraint is a spatial approach to CHP introduction within regional electricity networks. Local Authorities or Devolved Administrations would therefore require a clear indication from the Government to reduce Greenhouse emissions, in particular CO_2, otherwise it would be difficult for SMEs to relate the need for a national CO_2 reduction to a locally based operation. Although the survey results had identified that 75% of the respondents did not have an accredited environmental management system, it noted that 88% considered the avoidance of environmental levies as a potential reason for future investment in CHP. This is an indication that a spatial approach mandated by national instruments would be appropriate.

Developing any new policy framework based on a spatial approach would however depend on communication channels and the ability to influence the economic benefits of SMEs. Communication could be carried out in either of two ways, a sectored approach or a regional approach. A comparison of the attributes of both approaches are analysed in Table 7.1.

Table 7.1; A Comparison of spatial communication options for SMEs.

Positive Attributes		Negative Attributes	
Regional	**Sectored**	**Regional**	**Sectored**
Building Control	Support network	Deadweight	Complexity
Development Funding	Targeted information	Over investment	Limited SME participation
Opportunity benefits		Displacement	Focus on large businesses
Spatial planning			Inflexibility
Eco sustainability			
Knowledge bank			

Table 7.1 shows that there are more positive attributes for regional communication channel than for the current national communication channel based on business sectors.

The results of survey (question 12) had indicated that final decisions for CHP are taken by a Technical Director in conjunction with the Finance Manager. Therefore any communication tool needs to address both the finance and technical parameters. The use of a Self-Assessment Tool in the decision-making process, set within a regional context in terms of default parameters such as connection charges, tariff structures, would be useful to establish the viability or non-viability of a proposed CHP scheme. With a positive indication of viability, the information gained would be used to obtain the support of the Board of Directors.

7.6 Conclusion

The conclusion from the research is that the current Government policy framework is not sufficient and is ineffective to encourage the use of CHP by SMEs. A new policy framework is required that is based on the demand led policies as noted by SMEs from the research data. The proposal is that a spatial policy framework for CHP that seeks to respond to the demand patterns identified in the research such as plant replacement and project amalgamation as leaders for CHP would be appropriate. This should offer distinct advantages over the current supply-oriented promotional and marketing campaigns for CHP use.

Devolved Administrations, Regional Development Agencies and Local Authorities already have a remit to develop and monitor local air quality improvement plans (DEFRA, 2002c). Some RDAs such as the East Midlands Development Agency are already exercising this remit. Why not then a generic regional or local target for CO_2 emissions, which incorporates CHP as part of its abatement strategy and is to be reported on a Carbon Index basis? Such a target would be based on a new framework bringing together planning, taxation, business support and the management of local electricity networks. The communication strategy needs to be based on the importance of CHP within a context of regional planning for sustainable development such as is to be promoted by the Sustainable Energy Centres. Such a message would envisage the growth of CHP within a context of eco-sustainability as part of a holistic framework, which responds to plant replacement demands and offers appropriate measures to encourage SME managers to install CHP.

The key message for encouraging the use of CHP in an area based context would therefore not be its contribution to CO_2 reduction for the enterprise but its contribution to the development strategise of the area in which it is based and for which environmental accountability is now being sought by Government.

Within an area based strategy the use of CHP by SMEs would be enhanced by the use of planning guidelines in response to plant replacement demands and offer appropriate measures to inform SME managers about its. The new framework should therefore be coupled with a decision support tool, in the form of a BDSS operating within a regional framework of a Governance Support System. Consideration should also be given to the potential for unwarranted effects of grant subsidies normally identified as a weakness of area based management strategies. These include the potential for deadweight – where investment in CHP would have in fact been carried out (such as in Courtaulds), without the grant support Over-investment, as larger CHP plants than are required could be installed as a result of the grant availability and Displacement – where limited grant funds grants are taken up by less deserving SMEs, merely on a "first come first served" basis, leaving more deserving companies without the support funds to implement schemes (Armstrong, H. & Taylor, J., 1985:251). The use of a limiting spark spread value to manage a CHP Obligation would be offer considerable stability for small scale CHP investors who may not withstand large market fluctuations.

Chapter 8

New Decision Support Systems for encouraging the use of Combined Heat & Power in Small & Medium Enterprises

8.1 Introduction

The conclusion of Chapter 7 presents the opportunity to propose a new policy framework for the use of CHP in SMEs, based on the data collected in the research. It identifies the need for an alternative framework that would focus on demonstrating the combined financial, technical and environmental benefits to SMEs as part of an effective demand led communication strategy. The conceptualisation of a Governance Support System in Section 4.5, had sought to lay the basis of a new framework, aimed at improving communication to SMEs. The dominance of economic benefits coupled with plant replacement as key drivers for CHP in SMEs is not surprising, as the literature review noted that SMEs are motivated by short term financial gains (Section 3.5).

New data obtained from the research includes the significant potential to obtain user satisfaction for CHP when it is considered as part of a larger project. The objective of any new Governance Support System should therefore, be to target these twin criteria as opportunities for SMEs. To achieve this would require a coherent and co-ordinated framework for meeting SME expectations. There is also a requirement to develop the self-assessment capacity, based on an Index, for assisting in the decision-making process, which could also be used as a benchmarking tool.

8.2 A Local Governance Framework for Combined Heat & Power

The third assessment review of Climate Change Science reported on policy insights at the regional scale, as being an *"important and under -explored geographical and political area, for analysing the impacts and responses to global climate change"* (IPCC, 2001.) The rationale being, many of the systems affected most by climate change are regional in scope. Furthermore, that there is a better prospect for mobilising stakeholder interest and concern, if climate change impacts can be demonstrated on the ground, in familiar locations, and upon landmarks and businesses, than if impacts are analysed only at national or international scales. Nonetheless, the UK Government in promoting Devolved Administrations and Regional Development Agencies have sought to distinguish the powers of Regional and Local Authorities. In the main, these distinctions relate to planning and issues of environmental strategic importance such as waste management and air pollution.

Within the wider European context, a distinguishing feature between Local Authorities in the UK and those in other European Countries (except France) is the lack of responsibility for local energy planning and management. In the London context, the Greater London Authority Act (1999) requires the Mayor to prepare a state of the Environment report by 2003, to "*include information on energy consumption and on emissions that contribute to climate change*". The Government has previously been reluctant to move this level of governance from a central to a local or regional level.

The requirement for a regional governance structure to include energy management is one that was also identified by the Mayor of London as a key aspect for minimising the negative impacts of health in the local environment. The Mayor of London, Ken Livingstone, has therefore used his statutory power under the Greater London Authority Act (1999) for providing an Air Quality Plan, to include the development of a Regional Energy Strategy (GLA, 2002). The strategy refers to an energy hierarchy (Section 1.2) for guiding decisions on energy matters, where maximum environmental benefits are to be obtained when primary energy is used. It also offers scope for minimising the use of fossil fuels and for the use of "clean" energy production techniques, such as CHP.

The approach of the Mayor to area based energy planning mirrors those of other European Countries such as the Scandinavian Countries and the Netherlands. In particular, Swedish Municipalities exercise a considerable amount of influence in energy and environmental planning, within the remit of the 'Act of Municipal Energy Planning' (1977). In the Czech Republic after 50 years of centrally planned energy policies, Czech cities are now responsible for their own energy planning (COGEN, 2002). This is the result of the national Energy Policy of 2000 and the Energy Management Act, 2001, both laws that focus on ""the promotion of end use energy efficiency technologies".

It would therefore appear logical, on the basis of the responsibility for preparing a sustainability development plan (DEFRA, 1999d) for Devolved Administrations and Local Authorities to have the formal responsibility for local energy planning for businesses. These powers would be a natural extension of their existing responsibilities as some Regional Development Agencies (such as the "One NorthEast") currently manage business support projects. They have an overriding remit for building planning consents, The Local Agenda 21, and for implementing the Sustainable Energy Act (2003). Collier, U. & Lofstedt, R. (1997: 25-39), note this reluctance to devolve energy planning as part of the operational constraints of U.K Local Authorities. They further record that "*UK Local Authorities do not have a constitutionally assured allocation of competence and are only able to act under the specific direction of Parliament. These constraints do have important implications for local climate change policies, with budget constraints probably the most important factor*".

The recent adoption of a Supplementary Planning Guidance document for energy efficiency and renewable energy use in new developments by Leicester City Council (LCC) is evidence of a changing role for local Authorities in the area of sustainability planning (LCC, 2002). The guidance notes that *"planning applicants will be strongly encouraged to provide an assessment of the potential contribution renewable energy technologies and CHP schemes could make towards the energy requirements of any proposed development."* The London Borough of Waltham Forest are also having public consultations on the adoption of similar provisions in their Unitary Development Plan scheduled to be implemented in April 2006.

The argument for devolving environmental targets in the UK is not new. The House of Lords select committee on the European Communities had "urged the Government for the urgent improvement of the planning process", which it sees as a grave hindrance to achieving the necessary growth in renewable energy (ENDS: 294, 1999). The modernising Government White paper (DTI, 1999) had earlier committed the Government to an integration of the wider economic, social and environmental impacts for Devolved Administrations and Local Authorities. This commitment led to the development of the mandatory Regulatory Impact Appraisal (RIA) for the assessment of sustainable development impacts. The Government has also sought to encourage the implementation of the Energy White Paper commitments, by setting up a number of delivery mechanisms for encouraging an integrated approach. An example of these agencies is the Sustainable Energy Policy Network, tasked with ensuring the right communications and links are made across and beyond Government to deliver the Energy White Paper commitments (www.dti.gov.uk/energy/sepn). The Sustainable Development Research Network (SDRN) is also seeking to lead the academic forum, through research of the links between sustainable development, regional economies and economic growth. They have noted that "*Decisions affecting sustainable development are made in the absence of the information and evidence that would inform a socially inclusive policy approach- and this may end up being to the detriment to the original policy decision*" (Eames, M & Adebowale, M., 2002).

The Government's Sustainable Development Strategy (DEFRA, 1998b), is also based on indicators (Table 8.1), and are measured on a regional level.

Table 8.1 National Indicators of Sustainable Development,

Days of high/moderate air pollution[41]*	Investment in public/private assets*
Employment	Qualifications at the age of 19
Expected years of healthy life	Homes judged unfit to live in
Level of crime	Emissions of greenhouse gases*
Gross domestic product	Road traffic
Population of wild birds	Rivers of good or fair quality
New homes built on "Brown Field" land	Waste arising and management*
Satisfaction with the quality of life	

Source; DEFRA, 1998b

Inherent within Table 8.1 are environmental indicators noting the importance of integrating environmental, social and economic issues at a local level. Table 8.1 also offers scope for measuring the economic, social and regional development of a region. There are four indicators with particular relevance to CHP; the minimisation of air pollution, the reduction of greenhouse gases, making use of the energy in waste, investment in public/private assets.

[41] Those asterisked sustainability indicators, are elements that are influenced by the use of Combined Heat & Power systems in any region.

All of these indicators refer to a need for investment in clean technologies, such as CHP, towards achieving the Government's sustainable development targets. The strong support for CHP in the Mayor's energy strategy is recognition of the contribution CHP can make in improving London's environment.

A new governance framework for spatial energy management, which incorporates CHP, would therefore offer a new platform for increasing its use in SMEs. It allows for the integration of policies for improving the economic and environmental aspects of the SMEs performance, as part of a coordinated strategy. The use of the proposed governance framework is also important, because it allows for inclusion of environmental targets in area based planning issues and in the enforcement of planning regulations. The role of Development Agencies and Actor Networks could then incorporate the responsibility of providing energy advice and support to SMEs, particularly where planning issues are concerned. As an extension of this, it could then be argued that specific CHP capacity targets should be included within the remit of regional sustainable development plans, as required by the Government. (ENDS: 295, 1999).

8.3 Promoting a single Governance Framework for Embedded Generation

It is clear from the research that CHP installations are frequently linked to the solution of a technical problem, generally at a time of plant replacement. In the development of a policy initiative for encouraging CHP use, it may be prudent to consider strategic alignments that may assist in raising the profile and consequently a wider recognition of the barriers to its use. The need to encourage the use of clean energy production techniques, and the similarities between technical barriers to CHP and Renewable Energy, lend support to an argument for the amalgamation of policy initiatives for both technologies.

There are many examples of a policy shift of CHP closer to Renewable Energy. The full exemption from the Climate Change Levy for energy used or produced from both technologies, the full exemption from business rates and capital allowances are all examples of the fiscal advantages they enjoy. The setting of specific capacity and CO_2 abatement targets for both technologies is a further example of the closeness of the two technologies. Both technologies also suffer from discrimination for the electricity industry in the distribution of electricity through existing networks

There has already been recognition of the need for policy integration from the Government. In 1998, the Minister of Trade and Industry, Peter Mandelson in setting out the Government's Renewable Energy Obligation (DTI, 1998), referred to the CHP capacity target as comparable to the new renewable energy target of achieving 10% of the national electricity production by 2010.

This was a significant recognition of CHP as having a direct relationship to renewable energy. The Mayor of London's integration of CHP and renewable energy into a single energy reduction and CO_2 reduction target for London is further recognition of the need for an integrated approach on a local or regional level.

The use of a combined policy framework is considered important, because the use of renewable energy sources is also noted in the Energy White Paper as the longer-term logical consideration for meeting the tripartite concerns of security of supplies, climate change and increased electricity demand (DTI, 2003). It can be surmised that only CHP offers an important short to medium term solution, within the time frame for reducing CO_2 emissions towards the Kyoto target.

Combining the policy frameworks is a solution that is required during a period when the significant high capital costs of solar energy equipment, distribution systems for irregular supplies from Wind Turbines, and Solar Photovoltaic systems are being researched in order to bring costs down to a level that would offer the prospect of mass use. Indeed other more challenging technologies such as those for exploiting tidal wave or geothermal energy may not offer any significant contribution to the electricity supply network during the period leading to 2010.

The interview with the representative of the RECs (34-35) suggests that the use of micro turbine CHP would also offer a greater range of equipment for SMEs to choose from. He however notes the difficulties of distributing the surplus power generated as, *"the considerable difficulty of the RECs moving towards a greater flexibility for the connection procedures and the use of a more transparent charging system for such small-scale embedded systems based on the premise of location, location, location".*

The key advantage of CHP over other forms of renewable energy sources for meeting the Kyoto target is that it offers a middle ground between the larger power stations of about 100 MWe and the much smaller local solar PV systems of about 3 KWe. CHP schemes, based within a locality could be designed to meet heating/electrical demands of the whole commercial site, also minimising distribution losses and the use of limited supplies of fossil fuels. At an EU sponsored Conference of European Local and Regional Energy Management Agencies, this advantage was explicitly stated by the Commissioner responsible for the Energy and Transport Directorate, Henreich, G. (2001) as *"It does not make sense to produce renewable electricity with an expensive solar technology and then use inefficient boilers to produce space heating or lose it in inefficient buildings. Our drive should be towards finding an overall increase in the energy productivity of our buildings or plants that serve them. Only CHP offers this solution".*

8.4 Proposing a New Governance Support System (GSS) for the use of Embedded Generation Systems based on spatial boundaries

The discussion relating to the conceptualisation of the framework for the proposed GSS was carried out in Section 4.5. The conceptualised framework was depicted as Figure. 4.5 based on the outline data from the literature review for this Thesis. It offers a structure that incorporates a strategy for the national Governance of CHP policies. Consequent on the data obtained from the research, a number of new elements have been incorporated into Figure. 4.5 in order to reflect changes, which are intended to encourage a greater use of CHP than is presently the case. Figure 4.5 is again presented as Figure 8.2 for ease of comparison with the proposed new framework, Figure 8.1, which is developed by using the data obtained in the research as a new GSS. The new elements are colour coded for ease of reference and shown in Table 8.2.

Table 8.2 Introduction of the proposed GSS into spatial management

Code	*New Feature in the Governance System*	*Order*
Dark Yellow	A single, local communication channel providing Information and technical advice including internet access in conjunction with national energy networks and Planning departments.	1
CHPA	Allow for regional mapping of utility networks for the facilitation of easy entry conditions for embedded generation. Reducing the negative effects of NETA within the region by encouraging "Island Embedded Generation"	2
Lime	Monitoring of plant replacement through the planning/building control process on the basis of proving "avoidable use".	3
Blue	A regional approach to the disbursement of all grants and encouraging the use of ESCO's to ensure the efficacy of plant size and operation of embedded generators.	4
CHPA	Reducing the negative effects of NETA within the regional by encouraging "Island Embedded Generation"	5

Figure 8.1 Proposed Framework for the Governance Support system for Embedded Generation

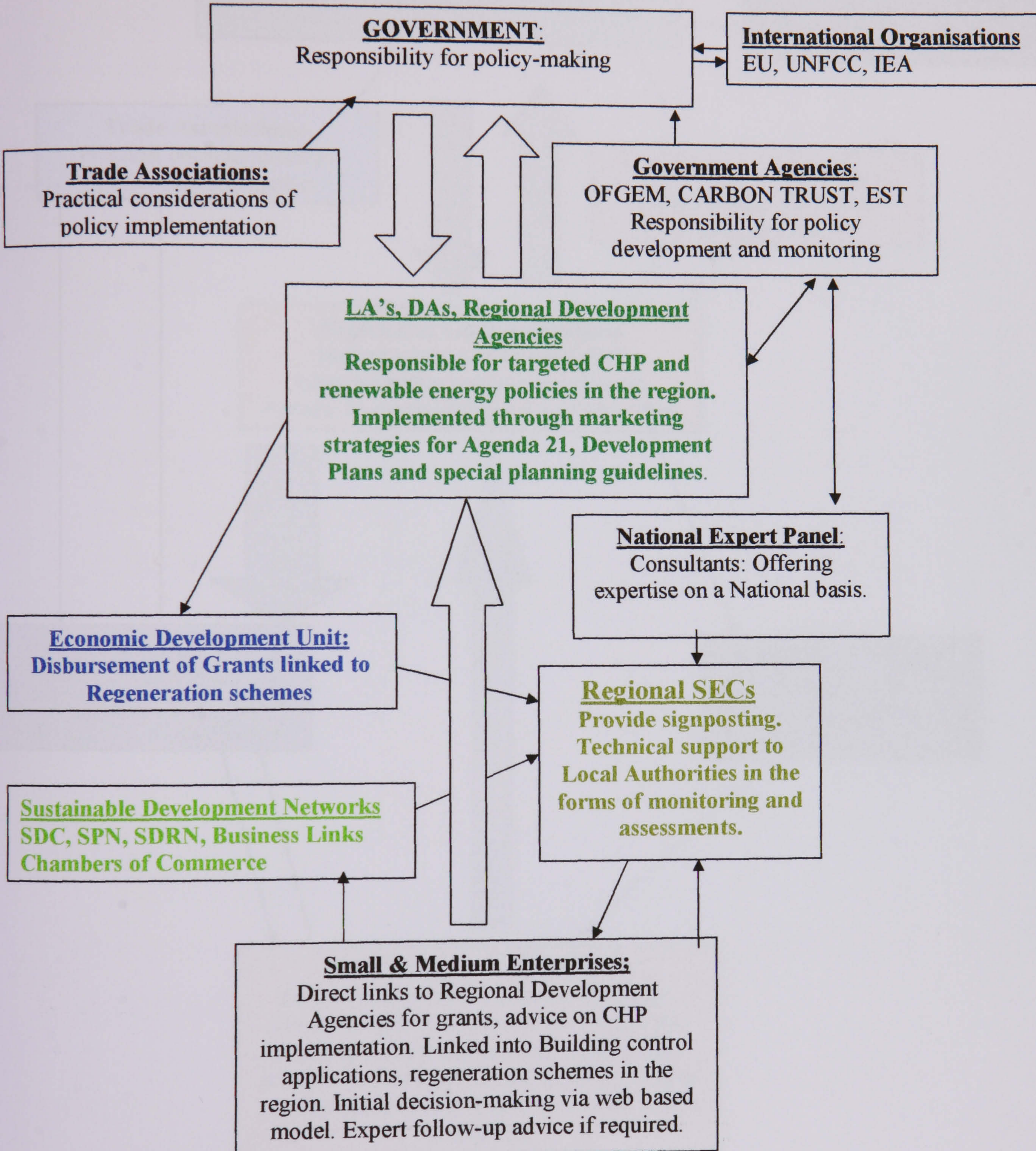
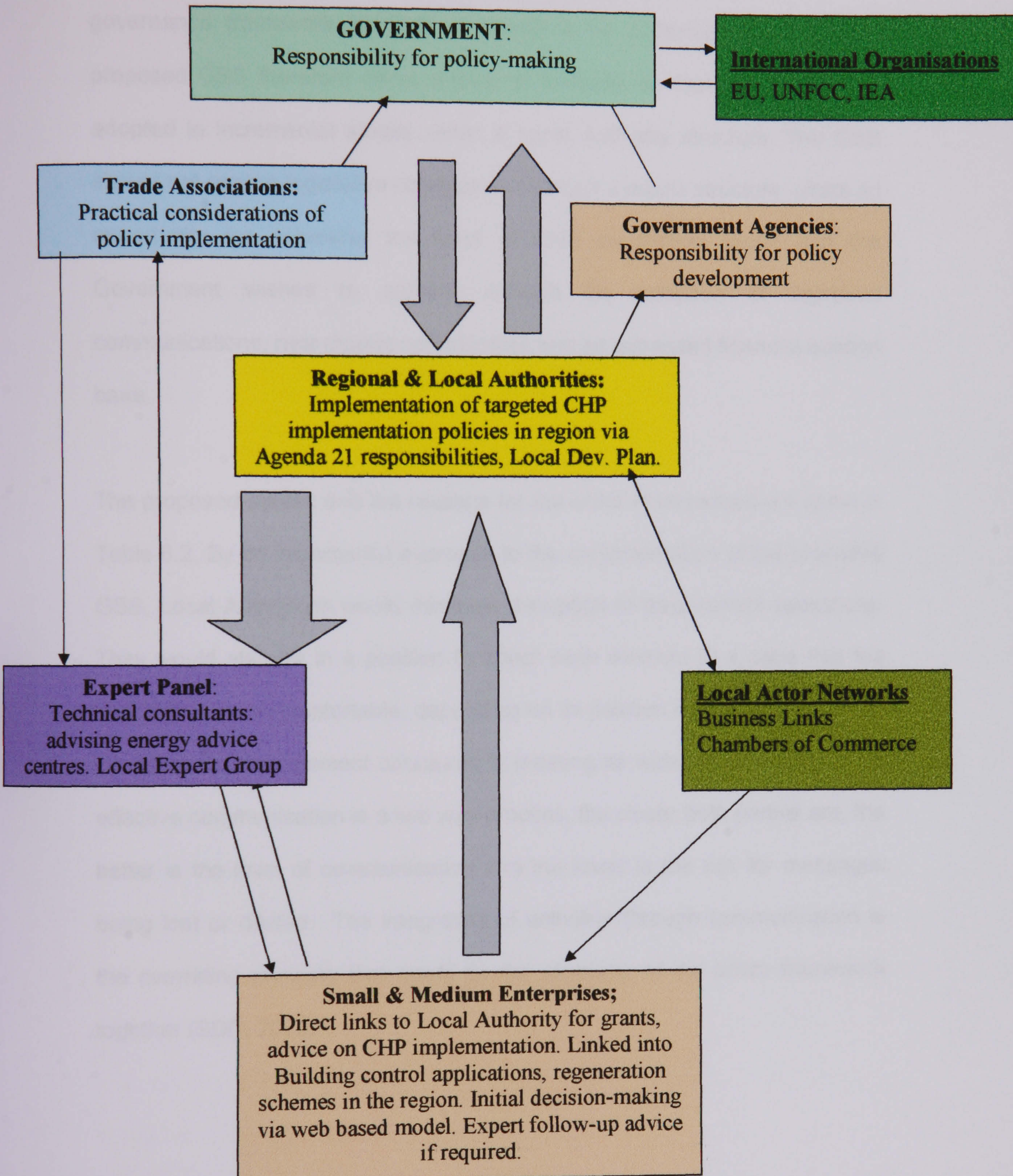


Figure 8.2: Concept of the proposed Governance Support System



For the proposed GSS to offer a practical and real alternative to the current governance framework for CHP, it needs to be a flexible structure. The proposed GSS therefore offers a level of flexibility, so that it can easily be adopted in incremental stages within a Local Authority structure. The GSS should not require legislative changes and though a robust structure, offers an opportunity for achieving the level of CHP installation target that the Government wishes to achieve through the adoption of improved communications, new market opportunities and an expanded financial support base.

The proposed stages and the reasons for the order of increment are given in Table 8.2. By an incremental approach to the implementation of the proposed GSS, Local Authorities would minimise disruption to their current operations. They would also be in a position to adopt each element at a pace that the region finds most comfortable, depending on its position in the cycle of setting up adequate management structures in meeting its wider responsibilities. As effective communication is a two way process, the closer both parties are, the better is the level of communication and the lower is the risk for messages being lost or diluted. The integration of activities through communication is the overriding principle that would tie the elements of the policy framework together (SDC, 2003)

By the use of the new governance framework, which has shorter links between decision makers and clients, there is an opportunity to integrate CHP issues within the wider communication framework for development in the region. It is therefore possible to increase the awareness of SME managers about the potential for CHP use in SMEs. The Finance Act, (2002), which allows the use of Enhanced Capital Allowances for third party CHP investment, goes some way towards encouraging the use of third party financiers. The Government, in devolving targets for CHP to the regions, could also devolve the grants budgets on a regional basis. The Local Authority would offer grants to developers and SMEs, who would apply for planning permission, on the basis of a pre-consideration for CHP. This would mean an imperative of proving that CHP is not a viable proposition, before planning approval for the installation of alternate equipment would be given.

Although the adoption of the proposed GSS addresses the policy framework within which a SME operates, it does not offer much scope for addressing the internal decision making factors. These are the internal factors, which also influence the decision-making process and for which Figure 4.10 was conceptualised to address. The development of an internal business tool, a self- assessment tool for use by SME managers, should assist in the decision-making process if designed to act as a suitable compliment to the GSS. This tool would also assist in linking the wider area and national interests with that of the individual organisation.

8.5 Developing the new Business Decision Support System (BDSS)

The SMEs who participated in the research survey on their use of CHP, noted that the main difficulty they encountered was the lack of an independent decision making tool (Section 6.4). The research also identified the following characteristics of those SMEs who operated CHP systems:

- Annual turnover of over £2.5m, annual utility costs exceeding £50,000.
- Considered CHP at a time when there was a need for replacing energy producing equipment or attended a local development initiative meeting.
- The need for cost savings and reducing energy consumption.
- Prefers to have access to grants or third party finance for a scheme.
- Would allow a risk of up to 42% of its electricity being supplied by CHP.
- Would allow a maximum downtime of 15%, minimum utilization 85%.
- The CHP plant is to be installed by the CHP manufacturer or specialists.
- Would prefer to use its own staff for a self-assessment of the CHP potential (using consultants if there are complexities with the scheme), as beneficial in convincing senior managers of the benefits of CHP.
- The scheme would be financially evaluated with a maximum payback of 6 years, or an Internal Rate of Return (IRR) of 12%, not withstanding the financing costs.

In the development of an integrated decision support system for energy policy management across the EU, Gheorghe, A. (1999) reiterated the problems of decision support systems within the framework of energy policy management and noted "*the importance of using indicators to reduce the complexity of energy systems selection*". The use of indicators suggests that for SMEs liable to use CHP, an 'easy to use' appraisal mechanism in the form of a Business Decision Support System, would be an appropriate tool. The regular use of consultants and manufacturers, identified in the research (Section 6.5) had pointed to the limitations of SME managers in carrying out a full CHP technical appraisal.

The BDSS is therefore to be used in assisting the creation of a structure to the decision-making process, based on futuristic assessments of equipment performance, energy demand and utility prices. Many decision support systems are represented in the form of mathematical models. It is not sensible however from a human point of view that acceptance of a solution changes from entirely feasible to completely infeasible with vary small changes in mathematical parameters (Canz, T. 1999). The development of the BDSS in this research therefore builds on the Commitment Theory (Section 3.6), and as such brings in to the decision making process the qualitative aspects of the manager's own experience. Should this theoretical appraisal indicate a positive outcome, the manager would have ready access to financial assistance/expert technical advice at a local level, with the ability to network with other potential/existing CHP operators.

8.6 Operational characteristics of the Business Decision Support System

The concept for a Business Decision Support System was originally shown in Figure 4.7 as an engineering plant appraisal model. It included parameters such as primary energy source, waste minimisation, and existing plant characteristics. This model was further expanded in Figure 4.8, in order to facilitate the ease of data input. As such, all the input units for the model were defined in advance, ensuring the integrity of the model and enabling the model to be set up as a dynamic model in the form of a spreadsheet using Microsoft Excel and Access. As there are a wide variety of situations that could benefit from CHP schemes displacing (fully or partially) conventional boiler or electricity based heating systems. The BDSS would be applicable to the majority of the types of CHP schemes that could be proposed.

There would however still be the need to undertake specific calculations for complex schemes, particularly where there is a combination of fuel inputs and multi-site organisations or where the conventional alternative to CHP utilises different fuel types such as biomass and gas. In order to develop the new micro appraisal system, consideration was given to the cognitive engineering design process that is used by technical consultants for appraising individual CHP schemes.

The data obtained from the research were incorporated within the model in Figure 4.8, in order to develop a meaningful BDSS, which includes:

- Using default values identified in the research for background analysis.
- Identifying the load profiles of CHP use in different sectors e.g. Offices.

- Incorporating a database of equipment performance as default values.
- Use of marginal analysis techniques for CHP appraisal
- Incorporating the opportunity costs of alternate plant consideration.
- Use of Life Cycle Analysis for CHP scheme appraisal.
- Use of performance indicators for benchmarking.
- Use of an integrated Decision Support Index.
- The use of degree-day data for assessments of regional variations.
- The incorporation of organisational factors, such as technical expertise for maintenance or the use of third party specialists.

The proposed BDSS therefore seeks to limit the technical content of the initial appraisal, so that its object is to establish the extent of a theoretical basis for CHP viability. It is in effect a business viability model, with an environmental and technical emphasis. The important factor is the initial involvement of the decision-maker in the appraisal process, in a way that would encourage a greater future commitment, should there be an indication of viability.

This simplicity of the BDSS dictates that prior information is already determined and available within the framework of the GSS. The essential link between the two Decision Support Systems, the GSS & BDSS, is the recognition of the need for active communication strategies, linked to regional sustainable energy development. The basic principle of operating the BDSS is to ensure that the user is able to enter easily identifiable data. All other useful technical data would already be incorporated in the model, to enable the identification.

8.7 The use of Performance Indicators for Decision Support

There is still some debate within the DTI on the appropriate form required of businesses for reporting an Environmental Performance Index. The expression 'resource productivity' is now more regularly used by the DTI (ENDS: 313, 2001), as a means of using indices for Corporate Environmental Performance reporting. Young, C. & Welford, R. (1998: 41-43), advocate the aggregation of a number of indicators, brought together from separate categories of the data, into a more general category. They note "*aggregated indicators are useful as they can bring together a large amount of data and express it in a single value*". The intention, when developing the BDSS, would therefore be to use an aggregation of indicators to develop a single indicator of the likely feasibility of the CHP project.

The importance of environmental performance indicators is also highlighted by the development of the ISO 14031 Environmental Performance Standard guidelines (Young, C. & Welford, R., 1998: 41-43). Other sustainable development indicators such as those set out in the UK Government's Strategy for Sustainable Development as headline indicators are used to measure progress (DEFRA, 1999d). However, the Government's climate change programme (DEFRA, 2000b), sets a requirement for good quality CHP schemes,[42] to be given exemption from the Climate Change Levy.

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28 A good quality CHP scheme been generally referred to as a scheme that, subject to certain criteria, achieves a quality index >100% (DEFRA, 2000b).

This is the first use of a performance indicator for a small scale CHP scheme evaluation although indicators are commonly used in the macro DSS such as the PRIMES energy model (Antonou & Capros, 1999). Although the CHP Quality Assurance Indicator (CHPQA) (DEFRA, 2001) integrates environmental and technical aspects of a CHP scheme, it is not suitable for use as a decision tool in any analysis involving comparison of options. This is because financial criteria are not used in its determination.

The use of this indicator by the Government, therefore affords the opportunity to extend the notion of a single indicator to include financial decision-making criteria. Such an integrated indicator used in this model, is noted as the Decision Support Index or a Decision Support Indicator.

8.8 Analytical Techniques used in the Business Decision Support System

The data sets used in the evaluation protocols within the BDSS includes:

- Initial capital costs.
- Maintenance costs over the life of the plant.
- Replacement costs at the end of the life cycle.
- Operating costs during the life cycle.
- The current energy consumption (or expected consumption for new sites) and boiler efficiencies are used to identify the heat load.
- For new CHP schemes or for a replacement boiler, a comparison is made with a boiler of a similar heat output and known efficiency.
- CHP manufacturer's data is used to calculate the energy consumption after implementation, allowing for export of excess electricity generated.
- Energy saving is calculated in KWh/annum, by comparing the energy consumption before and after CHP implementation.
- Manufacturer's capital costs and maintenance data are used to calculate the level of savings to be accredited to the Decision Support Index.
- Lifetime energy and CO_2 benefits are calculated over 20 years.

The analytical techniques incorporated into the BDSS are discussed in three discrete analyses;

- Technical.
- Environmental.
- Financial.

8.8.1 Technical Analysis

In Section 2.2, there was a discussion of the benefits of soft energy measures. The use of the proposed BDSS is therefore recommended on the basis that consideration be made of the benefit of soft energy efficiency measures, in advance of the CHP evaluation. The BDSS involves a financial appraisal of the potential CHP scheme, determining the number, size, outputs, utilisation, and back-up source of the potential CHP scheme. It also takes into consideration any maintenance benefits of changing to CHP, installation cost, benefits of Climate Change Levy and the CHP quality assurance implications. The model uses financial appraisals of costs and savings to determine annual capital/revenue cost streams.

The outputs of the model do not offer a firm indication of the practicality of a CHP scheme, as it considers CHP in isolation of other site development factors such as space, noise etc. The BDSS is intended to identify the extent of the likelihood of a successful CHP scheme on the site. The main benefit of the BDSS is the simplicity of decision support it affords, by the use of a Decision Support Index.

The Decision Support Index is determined as a nominal figure from a mathematical amalgamation of weighted individual indices, i.e. financial, energy, environmental, organisational. A ranking scale is then used to identify levels of CHP viability on projected performance outputs from the model.

8.8.2 Environmental Analysis

Due to the economic benefits in avoiding the Climate Change Levy (Section 7.4), the scope for Environmental Performance reporting in the form of an Environmental Indicator is also incorporated in the model. This indicator is integrated with the other two indicators (financial and technical) to form the Decision Support Index for the potential viability of CHP on a particular site. The Environmental Indicator is determined by factoring carbon savings by comparison to a viable, alternative heat/electricity producing using the same primary fuel. The energy saving evaluation is based on determining the energy consumption of the site, before and after the implementation of the CHP scheme (expressed in gas equivalents). If the alternative to the CHP scheme is a total replacement or new conventional boiler(s), then it is the new conventional boiler efficiency that is used as the existing plant before a CHP evaluation is carried out.

8.8.3 Financial Analysis

The allowable cost of the CHP plant is the marginal (additional) capital cost of the CHP scheme, over the cost of the alternative replacement boiler or a new boiler (in the case of new scheme). The determination of the full cost of the CHP scheme therefore includes the CHP plant, associated pipe-work and equipment solely related to its installation. It does not include costs that are not directly due to the CHP scheme such as the replacement of internal property pipe work or radiators, where these would have to be installed for any boiler replacement or new installation.

Even where the CHP equipment is to be purchased through a financing scheme the basic capital cost of the equipment is used in the calculation. A third party financier's (ESCO) contribution towards the marginal capital cost of the CHP scheme could make the payback period for the CHP sufficiently attractive to ensure the implementation of the CHP solution.

The ESCO's contribution, as a proportion of the total marginal capital cost of the scheme (including any grant to the CHP applicant) is used as the basis for accrediting the level of energy saving towards the Decision Support Index. As the triple objectives of CHP schemes are economic benefits (cost savings), reduction of primary energy and environmental benefits, they are used as output indicators in the determination of the Decision Support Index.

The BDSS undertakes the calculation of energy savings, in terms of KWh/annum that is achieved under various CHP installation (engine sizes) scenarios. The model also calculates the cost effectiveness on an opportunistic basis, compared to the current method of providing the service, to allow the direct comparison of alternative schemes prior to a decision being taken to proceed with the scheme. The risk analysis and use of discounted cash flow analysis are also calculated within the model.

8.8.3.1 Cost Benefit Analysis

A general principle for any capital investment scheme is that the implementation of measures must provide a satisfactory cost benefit to the end customer. Three financial criteria are used in the Cost/Benefit analysis of CHP schemes. These are Net Present Value of the customer benefit, simple payback period and IRR.

These three criteria are used because they offer the manager (in particular the financial manager), further information relating to cash flow and balance sheet values of the worth of the asset, through the lifetime of the project.

The BDSS uses an amalgamation of these three financial criteria in the determination of the Financial Indicator, which in turn is used to inform the Decision Support Index. The BDSS incorporates following financial data sets:

-

- Capital cost of the CHP plant and associated equipment
- Opportunity costs of not installing alternate plant
- Cost of third party (or grant) contribution to capital cost
- Net saving in overall energy bills to the client
- Operating and maintenance costs of the CHP
- Income from exported electricity

The conversion factors used in mathematical calculations which underpins the model and a worked example of marginal analysis for a CHP scheme are the provided in Appendix 8.1 of this Thesis.

8.9 Mathematical principles underlying the appraisal methodology for the development of the Business Decision Support System.

Annual consumption estimates (MWh)
CHPe=CHP electrical rating

A=Total heat required in Building

B=Heat to be recovered from CHP (CHP electrical rating x 1.5)

C=Heat recovered from Boilers (A-B)

D=Fuel required for use in Boilers (C* 0.75)

F=Unit price of primary fuel (£/MWh)

Estimated yearly running and maintenance costs (£)

Bm=Boiler Mtce

Fb=Fuel costs (D*F)

CHPm=CHPe*1.1

CHPf=CHPe*3.4*5845

Total running costs (T) =Bm + Fb + CHPm + CHPf

Value of CHP output (£/MWh)

CHPev=CHPe*Unit purchase price of electricity

CHPhv=CHPe*1.5 *Unit purchase price of primary input fuel (gas, oil, etc)

Savings from CHP system (S)=T- (CHPev + CHPhv)

Initial Capital Outlay (£)

**CHPc= Installed Costs for CHP Equipment (CHPe*750)

Payback (Yrs)
Payback for CHP investment = $\frac{S}{CHPc}$

**The Installed costs may vary due to factors such as the cost of electricity, gas connections and cost of external consultants, where appropriate.

8.9.1:Key parameters for a marginal life cycle analysis for a CHP scheme

The costs related to the CHP installation are:

- Marginal Fuel Cost
- Life Cycle Maintenance Cost
- Amortised Capital Costs

The Benefits are:

- Avoidable electricity purchases
- Avoidable production of heat

8.9.2: The use of marginal costing in the CHP appraisal within the BDSS

Generally when used as part of the heating system a CHP unit should be run as an alternative to an efficient boiler. Therefore a choice has to be made whether to buy electricity from the outside and use the boiler for heating or to generate electricity using the CHP unit and recover the waste heat. To make a correct decision requires a calculation of the marginal cost or costs for which electricity can be otherwise generated. The heat produced is also valued as the avoidable heat that could have been produced from existing/new boiler plant. The marginal analysis includes the consideration of several factors.

- The cost of 'top-up' electricity purchased
- The cost of gas or fuel oil
- The heat production efficiency of the boilers
- Equivalent degree days calculation
- The heat production efficiency of the CHP unit
- Electricity generation efficiency of the CHP unit

- Maintenance costs

The cost of generated electricity will have two components.

i. Additional fuel cost due to a lower heat output efficiency of the CHP.

ii. Operating and Maintenance cost.

For each size of CHP the additional fuel cost can be determined as follows based on utility bills, site data and manufacturers data sheets.

Cg = Cost of fuel (p/KWh)

Eo = Electrical output of CHP unit (KW)

Ho = Heat output of CHP unit (KW)

Fi = Fuel input (kW)

Ub = Boiler efficiency (%)

Fx = Cost of extra fuel (p/ KWh)

$$Fx = \frac{1}{Eo} \times \frac{(Fi - 100\,Ho)}{Ub} \times \frac{Cg}{29.31}$$

The maintenance cost C_m can be determined as follows:

C_m p/KWh= Annual cost from supplier's estimate E_o x hours run and the marginal fuel cost is calculated as follows: $C = C_m + Fx$ (p/ KWh)

8.9.3: Economic Appraisal

For ease of clarification an example is given of an analysis for a 1MWe gas engine CHP installation, a marginal analysis to justify the cost benefit of the investment would be based on the following:

Base Data Assumptions:

1MW Electrical Output/ Efficiency 31 % (Output/ HCV fuel in)
1.65 MW Thermal Output / Efficiency 50 % (Useable Heat / HCV fuel in Jacket water, lube oil, flue exhaust gas)

0.6 MW Losses* 19 % (Losses/ HCV fuel in
*Radiation, ventilation, generator losses, heat not recoverable from

exhaust)

3.2 MW fuel consumption (H.C.V.)	100%
Notional Gas Cost	0.75 p/KWh
CHP Maintenance charge	0.9 p/kWh
Avoidable Electricity Unit Price	4.5 p/KWh
CHP Plant running in 'Normal' Mode	5,845 Hrs/annum
Installed costs for CHP Scheme	£700/KWh

(Excluding heat exchangers, control panel, & remote monitoring)

Marginal Fuel Costs

Fuel Consumption	1^{*1} / 0.31^{*2}	= 3.2 MW
Fuel Cost	$3.2 \times 9^{*3}$	= £ 28.80 /hr
Recovered Heat = $0.50^{*5} \times 3.2$		= 1.65 MW
Value = $(1.65 / 0.8^{*6}) \times 9^{*3}$		= £ 18.50 / MWh
Net Fuel Cost = (28.8 - 18.5)		= £ 10.30 / MWh

*1 Electrical output of chp

*2 Overall electrical efficiency

*3 Fuel cost (gas) £/ Mwh

*4 Maintenance cost (including availability guarantees)

*5 Thermal efficiency of CHP

*6 Seasonal boiler efficiency

Life Cycle Maintenance Costs

For an all inclusive 10 year warranty with guaranteed availability, the current unit cost is £12.50 /MWh and escalates at RPI. It includes:

- Scheduled and Unscheduled Maintenance.
- 90% plant availability Guarantee.
- Target 93-95 % ***
- Covers engine and all associated parts and labour.
- Cables, Switchgear, Pipes, Heat Exchangers, Controls.

*** Supplier pays losses for unavailability below 90%. With this type of contract availability is usually 93-95 % of requirement.

Amortised Capital Cost

Capital Cost of CHP	£ 700,000
Supplier Finance at	£ 12.50[43] / £1000[44] / month
Monthly repayments are	£ 8,750

For 24 hours / day, 93 % availability
The nett cost is £ 8,750/ 730[45] x 100 / 93 = £ 12.88 / MWh

Cost Summary	£/ MWh
Fuel	10.30
Capital	12.88
Maintenance	12.00

Total Cost of operating the CHP unit = £35.18/MWh
For an operating period of 5845 hrs in a year, cost would be £205627.1

Calculating the Cost/benefits of operating the CHP unit

Value of CHP output (£/MWh)
CHP Electrical output 1 x 5845 x £45=£263025
CHP heat output 1.65 x 5845 x £7.5=£72331.88
Total benefits from CHP system =£335356.88
Net benefit from operation of CHP system
£335356.88 - £205627.1 = £129729.78

Simple Payback $= \frac{£700000.00}{£129729.78} = 5.4$ yrs

[43] Escalates at 4% per annum over 10 years and can vary from £ 12.50 - £ 16.00
[44] Per £ 1000 borrowed
[3] Hours in an average month

8.10 Computer based examples of the Business Decision Support System

The floppy disk, which is presented as part of this Thesis, provides worked examples of how the BDSS model operates. Two examples are provided. The first example incorporates data taken from an SME in the list of surveyed businesses (Section 5.3) and shows that the SME that has a gas and electricity load, for which the use of a CHP system is suggested as a viable proposal. For this SME, the initial pages shown in Figure 8.3 are to be used for primary data inputs in order for a Decision Support Index to be calculated.

Figure 8.4 provides an indication of the calculated performance outputs of the model's calculations and provides an indication of the viability of the CHP scheme. A payback of 5.31 years, CHPQA of 135.5 and a Decision Support Indicator of 4, are all positive indicators that should lead the SME to proceed to a full investigation stage for CHP. Figure 8.5 is the output that the SME manager would initially be provided with and offers a graphical representation in addition to other energy and environmental benefits of the project for assisting with the decision process. The model is intended to offer the Decision Support Index as a definitive guide to the viability of the CHP scheme. The calculations of the se indicators are inherent in the model, and the model would be password protected so as not to be accessible without the required authority.

The second worked example shown in Figure 8.6 is of an SME, where the gas and electricity demand do not indicate a viable CHP scheme and where the Decision Support Indicator is 0. This would be an automatic indication to the SME that CHP is not suitable for the site and that other alternatives may be explored. In this way the BDSS offers a simple viability analysis, with an environmental emphasis of the consideration of the use of CHP.

Should a positive Decision Support Index be obtained, the relevant manager having already been involved in the initial decision process would then be more likely to proceed with the installation of a CHP plant.

FIGURE 8.3: CHP PROJECT ANALYSIS DECISION SUPPORT MODEL INPUT QUESTIONS					
Title of Project					
Date of Submission		Sep-02			
				True =1, False=0	
Type of Building			Office	0	0
			Factory	1	60
			Hospital	0	0
			Leisure	0	0
			Sewerage	0	0
			Hotels	0	0
					60
Area of Building (Sq M)					
				True=1, False=0	20 Yr Ave D/D
Regional location of Building			South East	1	320
			Southern	0	0
			South West	0	0
			Thames Valley	0	0
			Severn Valley	0	0
			Midlands	0	0
			Wales	0	0
			Northern Ireland	0	0
					320
Primary Fuel		Natural Gas	Solid Fuels	Oil	
		1	0	0	
		50	0	0	50
Existing boiler Details		Space Heating	Capacity (Mwh)	Age (Yrs)	Mtce Cost/Yr (£)
		1	1873	15	2250
		2		n/a	660
		3		n/a	
		Hot Water		12	400
Total			1873	15	3310
				True=1, false=0	
CHP Requirement			Boiler Replacement	0	0
			New Capacity	1	60
					60
				True=1, false=0	
Space Availability			Yes	0	0
			New Location	1	60
					60
					%
Energy Efficiency Measures			Building Insulation	Part	1
				Full	100%
			Double Glazing	Part	0
				Full	100%
			Pipe Insulation	Part	0
				Full	100%
			Low Energy Lights	Part	0%
				Full	100%
			Energy Mgmt System	Yes	0%
				No	

				True=1,False=0	
Key Staff			Technical Manager	1	50
				True=1,False=0	
Maintenance Capability		1	Own Staff	1	50
		2	Own Mtce Staff	0	0
		3	Manufacturer	0	0
					50
Average Fuel Prices				P/kWh	
			Gas	0.84	
			Oil	6.0	
			Electricity	4.4	
Utility Consumption		Primary Fuel (mWh)	Monthly Cost (£)	Electricity (mWh)	Monthly Cost (£)
	January	363	3049.2	175	7700
	February	313	2629.2	170	7480
	March	260	2184	189	8316
	April	203	1705.2	147	6468
	May	57	478.8	147	6468
	June	11	92.4	132	5808
	July	3	25.2	136	5984
	August	3	25.2	96	4224
	September	24	201.6	142	6248
	October	118	991.2	145	6380
	November	233	1957.2	159	6996
	December	168	1411.2	114	5016
Total		1756	14750.4	1752	77088

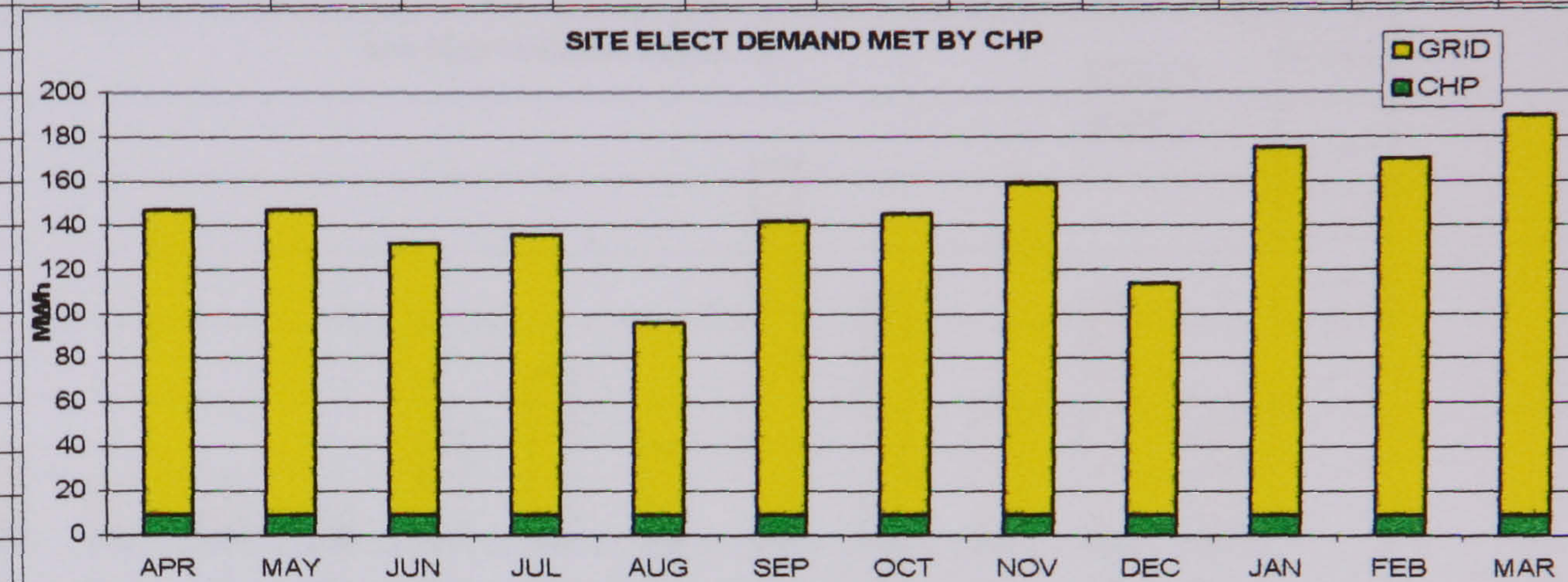
FIGURE 8.4: OUTPUT INDICATORS FROM CHP SCHEME APPRAISAL							
				NPV			
				Years	Exp	Inc	
CHP Decision Support Indicators				1	164910	31051	-133859
Energy Ratio	0.67			2	0	31051	31051
Carbon Dioxide Emissions/yr (T)	1753			3	0	31051	31051
Annual Energy Consumption (mWh)	3508			4	0	31051	31051
Annual Energy Bill after CHP	60787			5	0	31051	31051
Value of energy Savings per yr (£)	31051			6	0	31051	31051
Energy Savings per yr (kWh)	2362080			7	0	31051	31051
Carbon Dioxide Savings/yr (T)	2457			8	0	31051	31051
Budget Installed cost of CHP(£)	164910			9	0	31051	31051
Simple Payback Period (yrs)	5.31			10	16491	31051	14560
Area of Building (M2)	50000			11	0	31051	31051
NPV over 20 yr life	£79,385			12	0	31051	31051
Energy Cost Index (ECI) (£/M2)	1.2			13	0	31051	31051
Energy Use Index (EUI) (kWh/M2)	70			14	0	31051	31051
Carbon Saving Index (CEI) (T/M2)	49.14			15	0	31051	31051
Financial Saving Index (£/kWh)	£0.03			26	0	31051	31051
Investment Ratio	0.48			17	0	31051	31051
Emissions Ratio	1.40			18	0	31051	31051
CHPQI (Quality Index)	136			19	0	31051	31051
Decision Ratio	62			20	0	31051	31051
	62				181401	621027	
Decision Support Indicator	***4***						
INDICATOR CODES							
BAD	**1**			FALSE	FALSE	FALSE	TRUE
MARGINAL	**2**			0	0	0	4
GOOD	**3**						
VERY GOOD	**4**						
EXCELLENT	**5**						

FIGURE 8.5: CHP FEASIBILITY ANALYSIS

Projected Annual Energy Consm (Mwh) & Cost (inc.Climate Change Levy)

	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	Totals	
Gas	203	57	11	3	3	24	118	233	168	363	313	260	1,756	£ 1
Elect	147	147	132	136	96	142	145	159	114	175	170	189	1,752	£ 7

ASSUMPTIONS:-			
CHP Plant Electrical Output		230	KWe
Heat Output		354	KWth
Fuel Input		679	KW
Electricity Price (inc. 0.43p CCL)		4.40	p/kWh
Gas Price (inc.0.15p CCL+0.15 uplift)		0.84	p/kWh
Boiler Efficiency		75%	
CHP Maintenance charge		1.1	p/kWhe
Equivalent full load		490	Hrs/mth
ANALYSIS:-			
Electricity Displaced		10.12	£/hr
Boiler fuel Displaced		3.96	£/hr
Total Savings		14.08	£/hr
CHP Fuel input		6.27	£/hr
CHP Maintenace		2.53	£/hr
Total Cost		8.80	£/hr
NET CHP BENEFIT		**5.28**	£/hr
Carbon Dioxide Emissions (T/yr)		1,753	
Annual Energy Bill 2001/2002	£	**91,838**	
Annual Energy Bill after CHP	£	**60,787**	
Value of energy Savings per yr	£	**31,051**	
Energy Savings per yr		2362080	Kwhr
Carbon Dioxide Savings/yr		2457	Tonnes
Budget Installed cost of CHP	£	**164,910**	
Payback Period		**5.31**	Years
CHPQI (Quality Index)		**135.5**	
Exemption from CCL		QI > 100	
Decision Index		4	



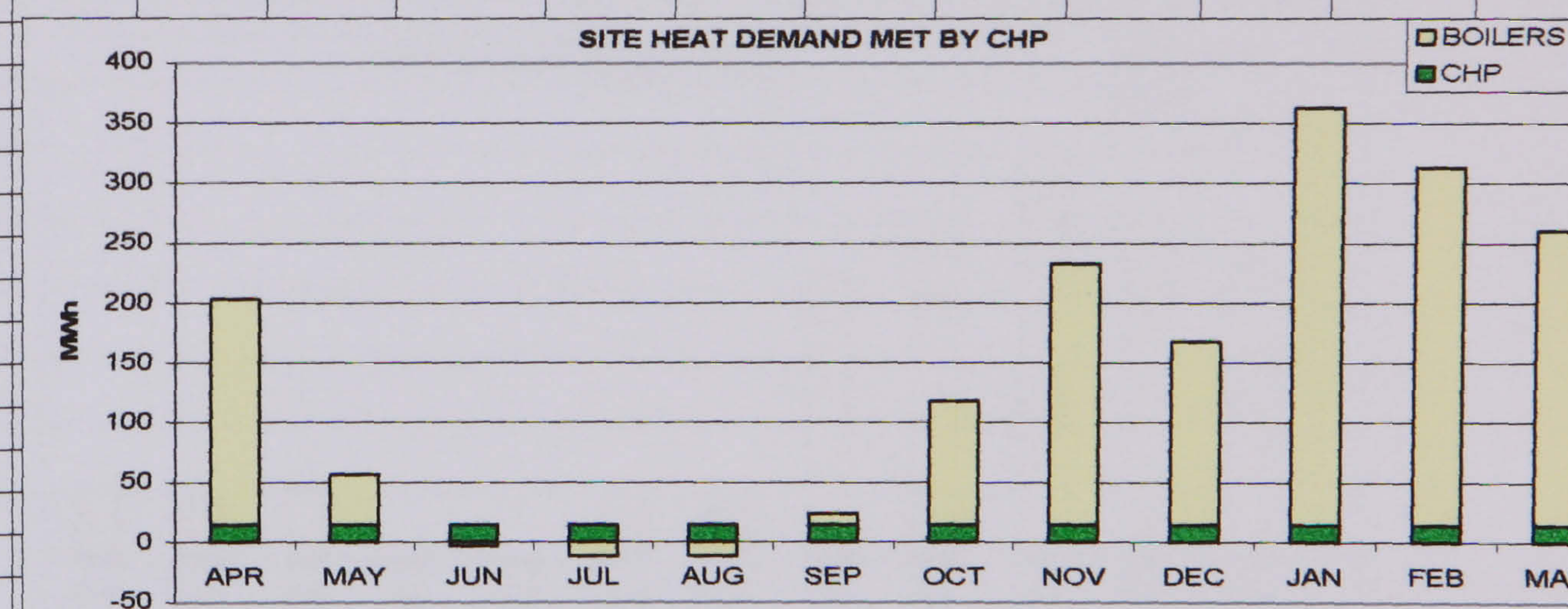
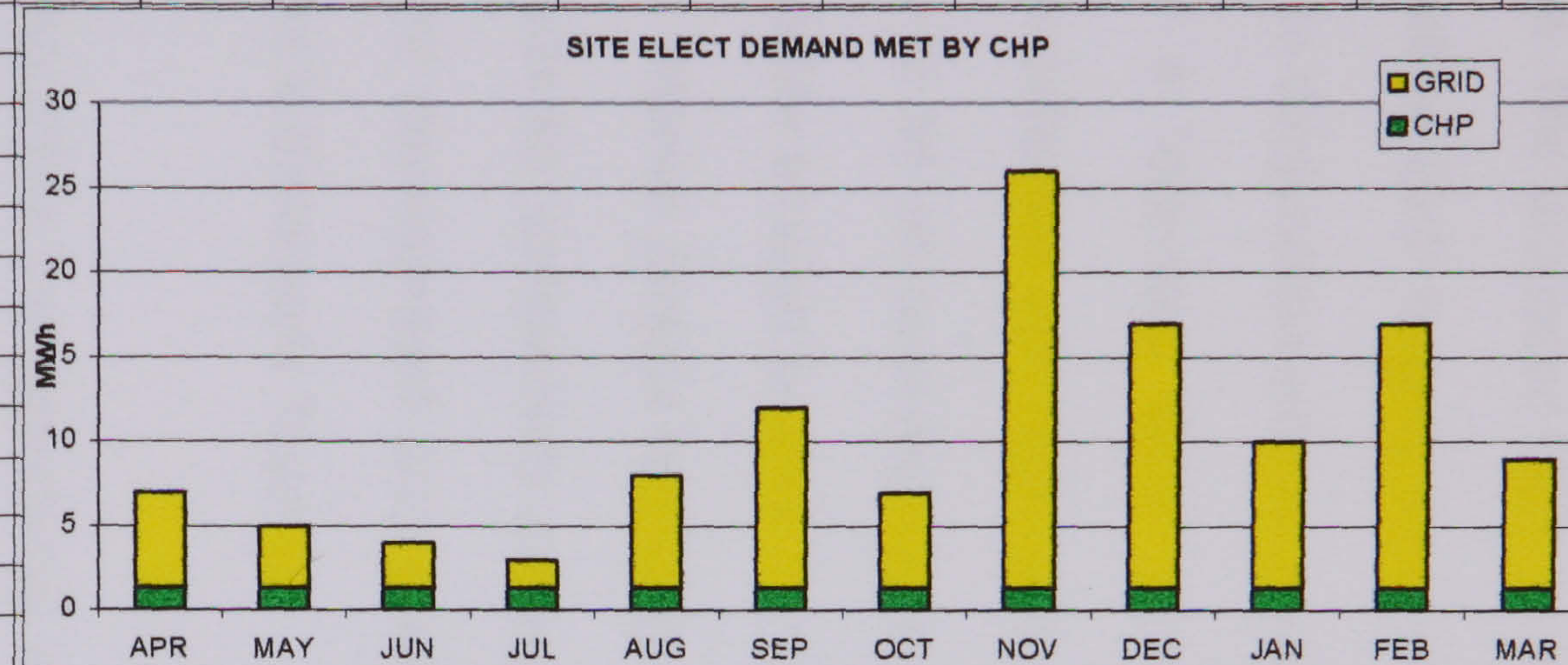


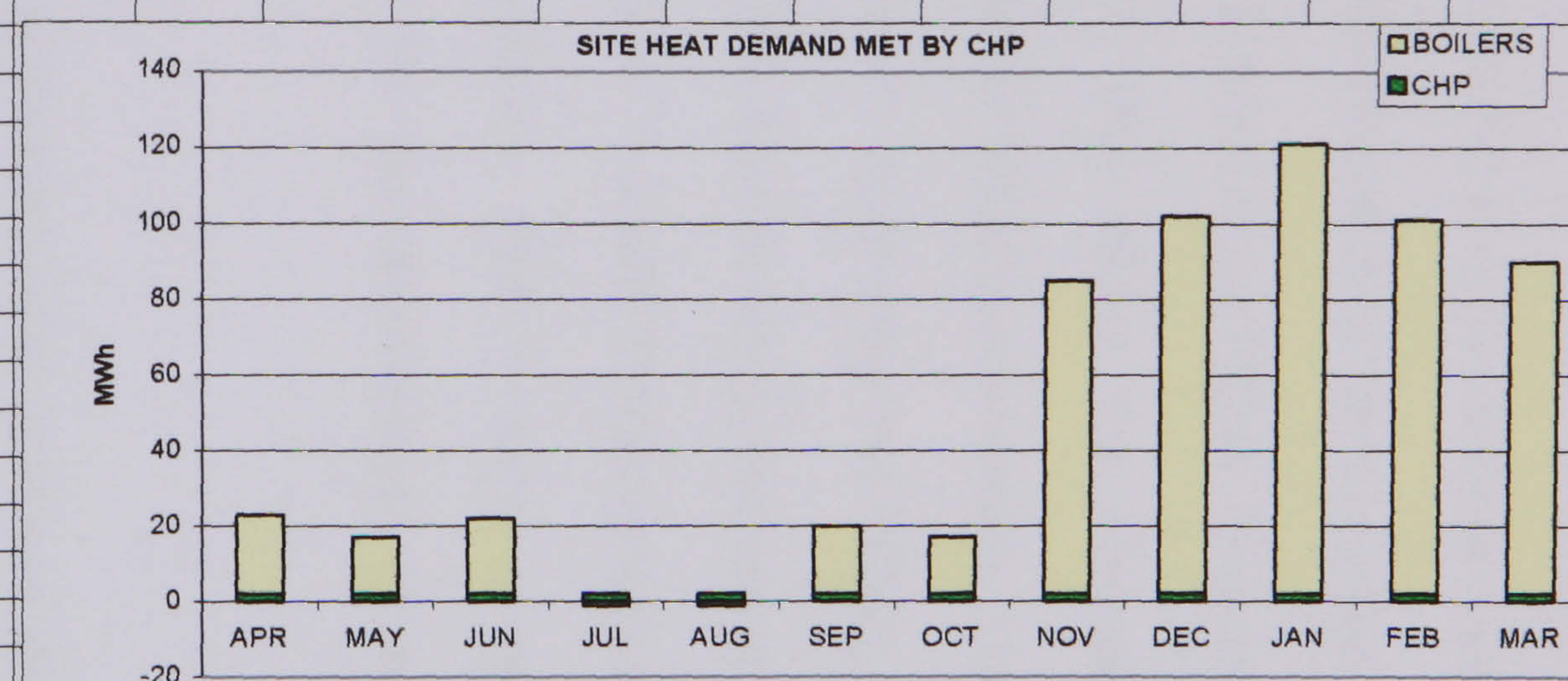
FIGURE 8.6: CHP Feasibility Analysis (indicating an unviable CHP proposal)

Projected Annual Energy Consm (Mwh) & Cost (inc.Climate Change Levy)

	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	Totals	Cost
Gas	23	17	22	1	1	20	17	85	102	121	101	90	600	£ 5,040
Elect	7	5	4	3	8	12	7	26	17	10	17	9	125	£ 5,500

ASSUMPTIONS:-		
CHP Plant Electrical Output	32	KWe
Heat Output	54	KWth
Fuel Input	116	KW
Electricity Price (inc. 0.43p CCL)	4.40	p/kWh
Gas Price (inc.0.15p CCL+0.15 uplift)	0.84	p/kWh
Boiler Efficiency	75%	
CHP Maintenance charge	1.1	p/kWhe
Equivalent full load	490	Hrs/mth
ANALYSIS:-		
Electricity Displaced	1.41	£/hr
Boiler fuel Displaced	0.60	£/hr
Total Savings	2.01	£/hr
CHP Fuel input	1.07	£/hr
CHP Maintenace	0.35	£/hr
Total Cost	1.42	£/hr
NET CHP BENEFIT	0.59	£/hr
Carbon Dioxide Emissions (T/yr)	225	
Annual Energy Bill 2001/2002	£ 10,540	
Annual Energy Bill after CHP	£ 7,077	
Value of energy Savings per yr	£ 3,463	
Energy Savings per yr	241920	Kwhr
Carbon Dioxide Savings/yr	324	Tonnes
Budget Installed cost of CHP	£ 44,544	
Payback Period	12.86	Years
CHPQI (Quality Index)	115.7	
Exemption from CCL	QI > 100	
Decision Index	0	





8.10 Conclusion

By removing supply labels such as specific technology types and placing a new emphasis on final service delivery, a new policy framework emerges which could be used as a platform for promoting all embedded generation technologies. The proposed GSS offers a strong and non-divisive framework that would allow CHP targets and CHP development to be managed on an area basis, in conjunction with renewable energy technologies. The proposed GSS offers a "one-stop shop" approach that allows the integration of development schemes with regional sustainable development plans. The GSS is designed to be an over-arching framework supporting the BDSS, which would be flexible enough to allow for different approaches by individual SMEs due to their internal project financing criteria. It would therefore serve as a consistent unit for comparison between regions, both in terms of regional environmental development and possibly for the development of regional trading blocks in Emissions Trading.

The GSS also offers the opportunity for signposting local demonstrations to potential developers, best value assessments, local awards, targeted training and education schemes, which may have particular relevance to the region and its needs. The proposed BDSS would not only offer a simple way of identifying a viability approach to CHP project appraisal, but would also be a useful tool in environmental performance reporting in SMEs. With the use of the BDSS, the SME has a simple mechanism to consider CHP as part of any proposal involving capacity constraints for heat or electricity in the business.

The BDSS would also be a useful tool to address the increasing pressure from the EU and the Government for Corporate Social Responsibility monitoring (ENDS: 318, 2001) and facilitate Environmental Performance Reporting for stakeholders. The progress towards a common European Energy market as indicated by the opening up of the European Electricity Markets and the European Union Emissions Trading Scheme (European Commission, 2001a, are all markers that the UK would eventually be brought "in line" with other European Countries.

This would necessarily involve devolving responsibility of governance for energy matters as part of a strategic regional requirement for sustainable development. The thinking within the EU is tending towards the ever-closer link between CHP and renewable energy (Section 8.3), which suggests that a proactive adoption of a single policy framework for sustainable energy development in the UK would offer easy integration into a wider European Energy Management Framework. The reality of achieving the benefits of CHP in the short to medium term and that of renewable energy technologies in the long term makes a strong case for an integrated local strategy to include both technologies within a single governance framework. The significance of a combined policy approach is that any new governance framework should not be considered as offering potential benefits only to CHP, but for all Embedded Generation Systems. Such an approach would also facilitate easier improvements to the electricity network infrastructure and for larger networked CHP systems to be developed on a regional level.

Chapter 9 – Recommendations and Conclusions

9.1 Introduction

The reduction of CHP capacity in the UK over the past 3 years has been generally linked to the effects of NETA and other technical barriers to it's use by SMEs. Whilst this may be a more generic view, there are other specific aspects that have not encouraged CHP take up in SMEs, partly due to the nature of SMEs and also due to the policy framework for encouraging CHP use by SMEs. It is perhaps symptomatic of a poor governance framework that academic and policy discussions about the limitations to the use of CHP have been generally shrouded around technical concerns and have not focused sufficiently on the characteristics of SMEs.

The Energy White Paper (DTI, 2003) confirms the Government's commitment to a CHP capacity target of 10gWe and a renewable energy capacity target of 10gWe by 2010. It does not however, encourage a link between the development strategies of the two types of technologies. It is this bridging between the demand and supply, between the various forms of cleaner technologies, between user's aspirations and those of supplies that has been a fundamental flaw in the current policy framework. By setting up the Sustainable Energy Policy Network as a link between the DTI and DEFRA the Government has however shown some recognition for an overarching framework of 'business and the environment' (DEFRA, 2002b), which does offer future scope for an integrated regional governance structure.

9.2: Achieving the Research Objectives

The objectives set at the start of the research study (Section 1.7) were to:

1) To critically assess the drivers and constraints for the use of CHP systems in UK Small and Medium Enterprises.

2) To assess the effectiveness of current Government policies towards increasing the use of CHP in Small and Medium Enterprises.

3) To develop a new policy framework for encouraging the use of CHP in Small and Medium Enterprises.

In assessing the drivers for CHP, the research concluded that the key drivers were economic and technical and that both were demand led, meeting the first research objectives.

- Economic drivers were determined by cost/benefit assessments incorporating financial assistance and third party funding.
- Technical drivers were plant considerations and operational reliability.

The themes developed from the semi-structured interviews and the data analysis led to the conclusion that the current Government policy for encouraging CHP use by SMEs, is ineffective, meeting the second objective of the research.

It was clear from the research study (Chapter 6), that there were inherent policy based anomalies in the way CHP systems were taken up by SMEs. These anomalies range from the timing of use, sizing of the CHP plant, dependence on financial assistance, lack of environmental imperative, limited effect of the climate change package of measures and in particular the effects of NETA, in terms of a limiting spark spread value.

The Decision Support Systems, incorporating the results of the research, therefore achieved the twin objectives of assessing the applicability of these drivers to individual SMEs and developing an integrated supportive framework that should encourage their use in SMEs. The Governance Support System is also designed to addresses the following strategic issues at a regional level:

- Communication within a supportive planning regime
- Regional infra-structural support for embedded generation systems
- Opportunities for local networking and best practice dissemination

The development of new structures for the GSS and the BDSS are therefore key outputs of the research study and meets the third research objective.

The incorporation of the BDSS as complimentary to the operation of the GSS, as well as being part of the operation of the GSS, is made as a claim for new knowledge in this research study.

9.3 - The Decision Support Systems-Implications for Local Authorities

The conceptual basis for the Support Systems is the improvement of the efficient use of primary energy sources in the drive towards sustainable development. The proposal in Section 8.4 of a framework that offers an area based governance for CHP, in conjunction with that of renewable energy sources, may have some resonance with the obligations of the UK under Agenda 21. Other potential benefits are the links with planning obligations that are being vested in Devolved Administrations and Regional Development Agencies. The proposed GSS provides scope for a mapping exercise in the determination of heat capacities and electrical supply points on a regional scale. This would form the basis of a communication and marketing campaign for CHP in the region and for businesses that may wish to consider CHP as part of an improvement scheme in their organisations.

Such a scenario is already the subject of a pilot research project in Texas, USA where the development of CHP based Energy Parks are being highlighted as particularly important for very large areas requiring high reliability of power supplies (Elliott, R., and Hedman, B., 2003). The use of the BDSS could be adapted to include the requirements of the Carbon Index method[46] (DEFRA, 2000c) for meeting the building regulations. The BDSS incorporates a calculation that offers carbon savings as one of its outputs, whilst also taking into consideration the cost and energy saving issues.

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[46] The Carbon Index (CI) is a calculation of SAP and CO_2 emissions used to calculate a carbon in use factor. It is expressed as $CI=17.7-9.0 \log_{10} (CF)$, where $CF=CO_2/(\text{Total Floor area} + 45)$ (DEFRA, 2000)

Regional Development Agencies (who could also devolve some powers to Local Authorities) could therefore use the BDSS as an indication of meeting the Building Regulations. With the setting of regional targets for renewable energy development (ENDS, Aug, 1999) the stage is set for targeting CO_2 reduction on a regional scale. The Local Authority Carbon Management Programme (DTI, 2003b) is further evidence of this. The Programme provides funding to Local Authorities to help them tackle their emissions of greenhouse gases, complimenting existing Carbon Trust programmes. With the increase in CO_2 emissions in the UK since 1997[47] (PRASEG, 2002a) and the limited growth of CHP (Section 2.7), Emissions Trading is also expected to take a central position in the Government's CO_2 reduction drive.

The Energy White Paper stated the Governments intention to "*make the new EU emissions trading scheme a central plank of our future emission reduction policies, through which the traded carbon market can set a signal for the value of carbon reductions in the economy*" (DTI, 2003a). Regional energy management therefore offers an opportunity to use the framework offered by the GSS in developing strategies for environmental support to businesses. They would be able to encourage them to use CHP, by identifying the benefits of emissions reduction in strategic development plans and in planning guidelines. By such an integrated approach to planning, local businesses would appreciate the key role of the authority in sustainable development planning.

[47] Carbon Dioxide emissions have risen by 1.2% since 1997, despite a self imposed target to cut Carbon Dioxide levels by 20% by 2101. Carbon Dioxide Emissions have only been reduced by 6.1% by 2002.

9.4 Challenges and Limitations of the Governance Support System.

In spite of the many and varied opportunities offered by the proposed GSS, its application may not be devoid of difficulties. The potential difficulties relate in the main to the changing environment within which it may have to operate with particular reference to Government regulations. The proposal to replace NETA with BETTA in 2005 is intended to bring the Scottish network in line with the English and Welsh networks is as a strategy to fulfil the White Paper commitment of a renewable energy target by 2010, as 60% of the renewable energy target is expected to be met from Scottish Wind Farms (Wilks, N., 2003). The rules governing NETA are however based purely on market mechanisms, with the price offered to the end consumer being the ultimate determinant of its success. The rules for incorporating BETTA should therefore seek to prevent frequent price movements that would be disruptive for SMEs planning to use CHP and indeed for domestic consumers.

Calls for taking the nuclear industry out of the remit for the Climate Change Levy; a separate CHP Obligation similar to the Renewables Obligation (DT1,2001c); and a much greater role for Local Authorities in Energy Planning, are all examples of changing energy scenarios. The flexibility inherent within the modular structure of the GSS would be useful in incorporating these changes in a meaningful way. The current move of a shift of focus for the EEACs from locally based domestic energy advice centres to a regional remit for Sustainable Energy Advice should also be appealing to Regional Development Agencies for incorporating EEACs into the proposed Governance Support System for enhancing CHP use by SMEs.

This would however necessitate a change in the current structure of the EEACs from not-for-profit organisations, in order to attract and sustain the level of expertise required to offer such a broad range of services. Devolved Administrations would need to examine their relationship with the emerging Sustainable Energy Centres, in order to ensure that objectivity in providing advice is maintained. The publication of the European Commission CHP Directive (EC,2003) and the Energy Performance of Buildings Directive (EC, 2002), are further examples of a changing legislative framework with which any new governance framework would be required to contend. The move towards regional sustainable development planning, also poses questions related to marketing and communication. Local Authorities have not been traditional sources of business advice and are frequently seen in a regulatory mode with regard to planning issues (Christie et al, 1995:198).

The potential for Regional Development Agencies to take on such a key advisory role may require considerable political will, both at the local and at the national level. RDAs would however have the opportunity of merging and linking energy and environmental messages with their role as developers and facilitators. The perception of inflexibility by Local Authorities, with respect to adapting to the requirements of change, would also not apply to RDAs. This therefore provides the RDA scope for meeting another challenging aspect of the Governance Support Structure.

9.5 The Business Decision Support System - A Tool for Best Value in the Management of Small & Medium Enterprises

The term "best value" is one that gained prominence after the introduction of the Local Government Finance Act, (1999). The Act requires Local Authorities to assess their own performance, not by isolated objectives of price and self-imposed targets, but by more subjective criteria of related determinants, such as service levels and satisfaction. This principle is underpinned by "the customer knows best philosophy". Another feature of best value is benchmarking, with respect to asset management and use. The ethos of "best value" is one that moves away from price and cost saving as the ultimate determinant of benefits. "Best Value" therefore offers a functionality of other benefits in public sector accounting, which, in the context of CHP, includes parameters of environmental benefits and energy saving.

"Best Value" is also in line with academic perspectives, of reducing the dominance of quantitative assessments in decision-making. Lovins, A., (2002), suggest that "*in future price may well become less important both for the demand side, where end use efficiency will be bought mainly for qualitatively improved services, and on the supply side where distributed and renewable resources will be bought mainly for distributed benefits*". The proposed adoption of the Carbon Index method (Section 7.6) as a planning application tool is one example of the use of 'best value' in Corporate Governance. Other examples are the inclusion of social and environmental performance in Corporate Environmental Performance Reporting.

Many businesses are already making voluntary statements about their role in society and the importance attached to their role in the community in which they trade (CBI, 2002). The use of the BDSS by SMEs could therefore be closely identified with the "best value" requirement for Local Authorities. The BDSS offers scope to SMEs to provide additional environmental indicators with respect to CHP use such as:

- Energy Cost Index (£/M^2) - The cost of energy (£) used in the building per unit of area as a result of the measures introduced.
- Energy Use Index (kWh/M^2) - The amount of primary energy (kWh) used in the building/unit of area as a result of the measures introduced.
- Carbon Saving Index (T/M^2) - The amount of carbon dioxide (Tonnes) saved in the building/unit of area as a result of measures introduced.

The indicators in the BDSS have been designed as energy and environmental performance indicators for the use of CHP in SMEs. The indicators could also be adapted within the organisation to compare the effects of environmental changes in the organisation through "before and after" calculations, for the incorporation of new technologies and systems which are designed to produce environmental benefits. The benchmark, Decision Support Indicator in the BDSS, also replicates the Energy Index, identified in the Energy Performance Indicator Method, which was developed for building energy assessments (Field, J. and Grigg, P., 2000). The method is the basis of the CIBSE Technical Memorandum, TM22, (CIBSE, 2002), and a tool for predicting the energy in use of a building, in a design process.

9.6 Review of the Research Methodology

The methodology used in the research dictated the approach to data collection and facilitated the use of the literature review for conceptualisation of the Decision Support Systems. An important outcome of these reviews and peer consultations was a contribution to the awareness of a distinction between the need for Governance Support System as an overarching framework and the Business Decision Support System for internal support to the SME. The direction of the research was therefore altered from its original perspective of a single decision support framework and led to the consideration of the characteristic and needs of SMEs at twin levels.

The dynamics of the CHP market were a feature in the research, as were the effects of Government policies, and the predicted environmental impacts of climate change (Section 1.1). The combination of these factors has led to regular development of policy initiatives both at national and international levels for their mitigation. Due to prolonged consultation periods and limited parliamentary time however, many of these policy proposals, such as the European CHP Directive (EC, 2003) are unlikely to become effective before 2005.

The research study was therefore concentrated on an incremental approach for a new policy framework required to encourage the increased use of CHP towards meeting the Governments targets by 2010 (Table 8.2).

9.7 The Future for Combined Heat & Power in Small & Medium Enterprises

A key factor that could influence the use of CHP in SMEs is how the technology might evolve to meet the needs of businesses. In Section 7.5 It was noted that there are limitations with the potential to introduce new CHP capacity into the existing distribution network without increasing the network strength. This limitation would have a short term negative effect on new CHP capacity and needs to be managed in line with the CHP growth potential. In order to address these concerns CHP systems would have to change and be made less complex and more adaptable to commercial buildings. The potential for "plug and use" CHP systems, in promoting its widespread use, follows the logic of developing a BDSS to assist in CHP decision making by SMEs. The logic is one of making the application simple, so that the manager does not feel intimidated by the technology, and therefore more inclined to consider CHP as part of new plant proposals.

A simplistic approach to the use of Combined Heat and Power in SMEs would be to attempt to present CHP as a "win-win" solution for environmental concerns. Such an approach would envisage offering a CHP Obligation incorporating a minimum electricity "buy back" price and a "heat obligation" price to ensure a transparent planning system for CHP and provide a recognition for CHP in the EU Emission Trading Scheme. These measures would probably satisfy all the concerns of the CHPA (2002a) and encourage new manufacturing capacity in the UK. The future use of CHP in SMEs is therefore dependent on the Government's recognition of the benefits of economic sector targets and the subsequent development of the necessary policies to encourage CHP use in all economic sectors.

Although the Government has adopted a policy of using fiscal measures to attract SMEs to environmental improvements, the introduction of new European Directives for CHP (EC, 2003) and for Energy performance of Buildings (EC, 2002), lead to a notion of an accelerating convergence in the management structures of energy systems within the EU. As a result of these directives, revised fiscal mechanisms by member states would now be required to meet new structures for the EU Emissions Trading Scheme. By making the building and the technology relevant factors in the promotion of CHP, SMEs are better able to relate the benefits of CHP to operational performance, than to a national target that may initially appear inconsequential to their operations.

The communication strategy, if based on an area strategy, could easily be incorporated into mainstream activities linking development planning with the use of CHP. Increasingly many European or national Government development initiatives are to be coordinated at a regional level for reasons of local accountability and subsidiarity. The SME should be encouraged to obtain the benefits of networking at a local level and use the local actors in the networks. Best practice innovative schemes could be easily replicated and the stringent energy requirement of planning legislation could be based on local requirements. This would also meet the requirements of permaculture and bioregionalism (Section 1.5).

The environmental challenge for area based energy management is to adopt a more pro-active role as opposed to the normally reactive attitude of Local Authorities. The lead by the London Development Agency to develop an integrated CHP/solar PV scheme in the Thames Gateway development area, the development of a single energy strategy for use of CHP and renewable energy in London (GLA, 2003), and the move by the Regional Development Agency, "One NorthEast" to make the North Eastern region of the UK a regional centre for renewable energy technology (www.one northeast.org) are all examples of the perceived benefits of a regional approach to energy management.

Other factors that would affect the use of CHP in SMEs are the extent of Bounded Rationality and Transaction Costs, which are closely related to the training of SME managers. Hale (1995) suggests that the development and use of cleaner technologies "*depend entirely on the priority given to the development of appropriate training strategies both internally and externally to SMEs*". An integrated training provision is therefore required that incorporates the environmental, technical and financial aspects of cleaner technology projects.

9.8 Further Work

The prominence of the Development Agencies as delivery agents for the GSS and BDSS pre-suppose an acceptance of a more active participation in area based energy management. It also pre-supposes a favourable economic climate in the period leading to 2010, when SME confidence would be sufficient for a consideration of large capital investment in plant. It would however be difficult to develop the Decision Support Systems, without a predetermined scenario for their implementation. As the merit of the systems would be in their flexibility of adaptation, further research on the possible applications of the Decision Support Systems would be required for their validation. The future research needs could therefore broadly be identified under the following categories:

(1) Development of the BDSS to incorporate the use of renewable energy sources such as wind/solar energy systems: The related barriers to both CHP and REST and their future roles as key facets of a low carbon technology make this a realistic outcome for the future. The current proposal for the BDSS does not take into consideration the variation in outputs from renewable energy sources such as wind and solar energy systems. In order to develop a reliable BDSS for use with renewable energy technologies, further academic work is required.

(2) Research the potential use of Hydrogen based fuel cells by SMEs: Fuel Cell CHP offers the prospect of continuous maintenance-free heat and power, obtained from a repetitive chemical process. This technology is still relatively expensive and has implications for greater safety considerations in its uses, than a conventional CHP system powered by natural gas. Fuel cells also have approximately 50% shorter life spans than fossil fuel CHP systems. The use of Hydrogen as a fuel in CHP plants also offers a significant opportunity for merging the use of renewable energy with the CHP technology and is yet another argument for a combined approach to the governance of CHP and renewable energy as proposed in the GSS.

(3) Assessing the applicability of the GSS with respect to the changing politics of spatial management such as Devolved Administrations: The Energy White Paper (DTI, 2003) emphasised the importance of local and regional decision-making for energy policy and sustainable development in delivering a number of national energy policy objectives. For the GSS to be successfully implemented, it needs to be robust, whilst also being flexible to adapt to proposed changes in European Union Directives and the opening up of new European markets. The potential difficulty of implementing the GSS depends on the change of regional government from a passive regulator to a proactive environmental champion, (Section 9.3) and would require further examination.

(4) A European perspective of the GSS, such as a comparison of its applicability to de-centralised energy planned countries: If the GSS were to offer any long-term role as a framework for encouraging the use of CHP in SMEs, it would need to be easily integrated with existing European Regional Governance frameworks. A pan European study could therefore test the flexibility and adaptability inherent in the current proposal.

(5) A transparent mapping exercise for a regional electricity network (11Kv) incorporating CHP: The development of Island or community networks is seen as alternate solutions to the potentially high cost of laying new electricity cable systems for access of Embedded Generation systems. The Texas study for developing energy parks in high electricity demand areas was noted in Section 9.3. A similar study in the UK would identify potential barriers to such an approach within the UK's electricity supply system. It would also be a useful mechanism to identify the full environmental value of heat from a networked CHP system, on a wider scale.

9.11 Conclusion and Recommendations

The conclusion of this Thesis is that the proposed Governance Support System would encourage the use of CHP in the SME business sector and would make an effective contribution to the achievement of the Government's CO_2 target by 2010. In relation to SMEs, this research has raised a number of issues relating to current Government energy policies, such as:

- The imperative for Carbon Dioxide reduction as a target, which has resulted in a wider utility price reduction.
- The appropriateness of an environmental policy, which is solely reliant on fiscal mechanisms for encouraging SMEs to be more energy efficient.
- The potential for conflict within the remit of the Carbon Trust; as the primary agency for Emissions Trading and for encouraging energy efficiency in small businesses.

The development of a single regional framework for the Governance of embedded generation is one that has evolved from the research as having the potential to encourage the use of CHP in SMEs. It is the use of the principles of "subsidiarity" and "joined up thinking" to address the challenges of climate change, security of energy supplies and the increased use of electricity. Developing new strategies also requires a better understanding of the development of future environmental management practices in SMEs. The role of the E U Emissions Trading Scheme, the proposed opening of the European Energy markets, are all going to be important factors that could alter the use of CHP in SMEs.

The move towards Corporate Environmental Performance Reporting (Section 2.2) for SMEs, coupled with limited knowledge base in the technical disciplines, and new fiscal accounting rules are also going to be the challenges for the 21st Century. The call by the CBI for direct and transparent energy taxes (CBI, 2002) is an example of the business sector accepting the notion of environmental taxation. The BDSS offers a way forward in this regard. These challenges would also require new internal decision-making mechanisms in order to ensure compliance.

The acceptance by Devolved Administrations and Local Authorities of their environmental responsibilities and the opportunity to incorporate energy efficiency matters into their traditional service delivery mechanisms, should allow for a realisation of the benefits of the GSS. A lead by the Government to increase the role of Sustainable Development Networks and Regional Development Agencies are useful catalysts to stimulate action by SMEs, in conjunction with the existing Carbon Trust and the Energy Saving Trust programmes.

The more central role offered to Devolved Administrations and Regional Development Agencies in the GSS, is perhaps the aspect that may eventually become problematic in future energy scenarios. The setting of environmental targets and in particular renewable energy targets for Devolved Administrations has meant that a small step change is required for them to have an overall CO_2 reduction target. Certainly the Sustainable Energy Act (2003), the European Emissions Trading Scheme, and the proposed emergence of Regional Sustainable Energy Advice Centres, augur well for a new environmental imperative for area based energy planning. Such an imperative would facilitate the use of the proposed GSS In pulling together a new and combined fiscal infrastructure for Embedded Generation.

It is therefore recommended that:

A new Governance framework for CHP be established, which would be an area based approach to energy performance targeting and includes devolving the national CHP and REST targets to a spatial level of management.

The proposal to revise the Building Regulations in 2005 (DEFRA, 2000d), would suggest tighter energy performance requirements in future buildings. Tighter regulations would lead to the use of more efficient boilers, making CHP as an option, more viable. Questions also need to be asked of the CHP technology. The CHP technology has existed since the late 1800s (the first

CHP system in the UK and was installed to serve the Manchester Canal in 1911) but has evolved little since then.

Changes in new CHP technology (as new ways are found to increase its appeal) are creating opportunities for the development of fuel cell technologies: hydrogen based systems and mini CHP systems. Fiscal allowances for research into alternate fuel technologies would stimulate the CHP market as cheaper and more sustainable fuel sources are identified. These are the likely scenarios in which the Support Systems may be operating. Their fitness for use would depend on the flexibility inherent in their design, the simplicity of adaptation between regional parameters, and the development of a knowledge base for the growth of CHP use by SMEs.

It is therefore recommended that:

CHP is established on a combined fiscal basis with renewable energy sources technologies, as part of a single commodity within the proposed Governance Support System for the European Union Emissions Trading Scheme.

A cultural dependence on Government grants has meant that the true economic value of CHP is not always identified (Section 6.5). The attraction for implementing the use of the Decision Support Systems would be evident in the opportunities they offer of improved communication with SMEs, integrated planning policies and development grants. Another argument for spatial environmental governance is the setting of local targets for sustainable development and renewable energy use.

Spatial governance would also facilitate the development of local actor networks for the dissemination of information, training and demonstration schemes relating to embedded generation.

It is therefore recommended that:

Local Authorities, Regional Assemblies and Development Agencies be empowered to include CHP as 'de facto' part of the planning requirements in all relevant cases.

The energy scenarios envisaged in the Energy White Paper (DTI, 2003), offers further scope for research into the application of the GSS and the BDSS. Although both systems are complimentary, changes in one would not necessitate changes in the other as they are both designed to offer benefits at distinct levels of administrations. The practical demonstration of a future potential for CHP lies in meeting the challenges posed by area based management in offsetting the concerns of bounded rationality and transaction economics. For SMEs these are major constraints for CHP, in addressing the seeming complexity of the technology and its economic viability. Any governance system that addresses these twin concerns should encourage much greater use of CHP in SMEs. The GSS and the BDSS are proposed as systems that offer a suitable framework to address these concerns.

It is therefore recommended that:

A new framework of communication should be adopted to empower SME managers, in the determination of the viability of a CHP scheme through the use of an interactive Business Decision Support System.

The expected start of the EUETS in 2005 (European Commission, 2000) would impose a set of regulations that would require particular governance structures such as are envisaged in the Governance Support System. The IEA (2003) notes the potential benefits for CHP in the EUETS with a particular emphasis placed on the CO_2 offsets from its heat and power supplies.

The steady decline in CHP capacity between 2001 and 2003 is a stark realisation of the failure of current Government policies. It is now time to make a bold move and consider new governance structures for encouraging the use of CHP in SMEs.

The changing scenarios for international and national energy management would undoubtedly require new approaches to the governance of CHP. A growing realisation of the importance of the SME market sector therefore offers a challenging opportunity to consider ways in which its potential can be harnessed towards a solution of climate change and other energy concerns.

This Thesis offers a way forward in this regard and offers a new policy framework, which if implemented would encourage an increase in the use of CHP in SMEs and ultimately offer strong assistance towards achieving the Government's key objective in its climate change programme, the reduction of Carbon Dioxide emissions and the subsequent abatement of global warming.

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APPENDICES 5.1-5.4

Dear Sir/Madam,

Decision Process: Combined Heat & Power (CHP) in Industry and Commerce

I am writing to request your assistance with a questionnaire for a research project, **which should take you no more than 10 minutes to complete**.
Climate change is the single biggest challenge currently facing the global community. Moreover, there is a broad consensus amongst the world's Scientists that Global Warming has already begun. Part of our Government's response to this challenge is to propose a levy on the business use of Gas, Oil & Electricity from the 1st April 2001. Good quality CHP schemes would have exemption from the levy, thereby reducing costs to businesses.
The research that I am carrying out aims to develop a decision-making framework for appraising new CHP schemes, drawing from the experiences of current CHP users like your organisation. New and existing CHP users may benefit from the decision model, which could be used as a simple and effective self-appraisal method, and could lead to reduced costs.
For the purposes of this questionnaire I am defining a CHP scheme as the Combined Heat & Electricity producing engine and only the additional equipment such as switchgear e.t.c. directly resulting from the CHP installation.
All responses would be kept confidential and used only for academic purposes. Respondents would be sent a free copy of the completed model.
Please return the questionnaire to Leah Corr in the reply paid envelope provided, by the 30 October 2000. I can be reached on 020 8521 8472, should you have any questions.
I value and appreciate your contribution and thank you in anticipation of your response.

Yours sincerely

Crispin D Webber
Researcher

The Director
XXXXXX
XXXXXX
XXXXXX

Dear -----,

<u>Developing a decision support model for improving the uptake of Combined heat & Power systems in Small/Medium Enterprises (SMEs).</u>

I refer to our recent conversation regarding my PhD research study and my request for an interview with you. The overall objectives of this four-year study are:

- To assess the drivers for Combined Heat & Power (CHP) in UK SMEs
- To produce a management decision model for use by SMEs in their consideration of CHP incorporating the government's strategy for CHP.
- To evaluate the business management response and validate the model.

I am therefore writing to confirm my request, in order to obtain your views on the some observations I have made after an initial desktop study of the OFFGEM database.

I am also proposing to send a survey questionnaire to named contacts of a number SMEs that have had CHP systems installed over the past 10 years. The information obtained from your interview and the questionnaire returns should assist me in addressing the objectives. I would be phoning you in the next few days to agree a time/place for the interview.

Please note that the interview would be private and confidential and all answers would be reported anonymously. The interview would be recorded on a portable tape recorder and the notes transcribed, used only for academic purposes. You also have my assurance that the information provided would not be used to seek any commercial advantage.
I do hope you can spare some time to meet with me.

Yours sincerely

Crispin D Webber
Researcher

Quantitative Survey

Section 1 –Information on the Organisation

(1) JobTitle______________________________________

(2) Level of Authority

Director ☐ Senior Management ☐
Head of Department ☐ Junior Management ☐

(3) Area of responsibility:

Operations ☐ Engineering ☐ Environment ☐

Finance ☐ Development ☐ Other____________

(4) Which of the following best describes the ownership status of your organisation?

Private Limited ☐ : Quoted Public ☐ : Government/Local Authority ☐

(5) What is your organisation's main operation sector?

Engineering ☐ Property Management/Domestic ☐

Food, Drink& Tobacco ☐ Textiles Leather & Clothing ☐

Paper printing & Publishing ☐ Public Service (State)____________ ☐

Construction ☐ Manufacturing ☐ Chemicals ☐ Utilities ☐ Hotel ☐

Transport ☐ Iron & Steel ☐ Agriculture ☐

(6) What is the annual turnover of your organisation?

Less than £2 million
£2 million or over but less than £5 million
Greater than £5 million

(7) How would you describe the location of the main building served by the CHP plant?

Individual building on own site ☐ Industrial Estate ☐

(8) What is the ownership status of the main building served by the CHP plant?

Own ☐ Lease ☐
Remaining period: ≤ 10 years ☐ : >20 years ☐ : > 50 years☐

(9) Does your organisation have an accredited environmental management system?

No ☐ Yes ☐ Please State______________________

SECTION 2-The decision process for the installation of a CHP plant

(10) Which of these sources of information on CHP has been or would be most useful to you.

	Very	*Not Very*	*No Use*
Govt Best Practice info.	☐	☐	☐
Self Assessment tool (New)	☐	☐	☐
Conferences/Seminars	☐	☐	☐
Consultants	☐	☐	☐
Industry Associations	☐	☐	☐

(11) What were the key drivers for installing C.H.P. (rank in order 1=best, 5=worst, if you can)?

Economic Benefits ☐

Financial assistance ☐

External Consultants ☐

Plant replacement ☐

(12) Who were involved in the final decision?

Energy/Environmental Manager ☐

Line Manager ☐

Finance Manager/Director) ☐

Director/Board/Committee ☐

(13) How significant was the awareness of legislation a factor to install C.H.P.?

Please tick: *Very* ☐ *Not* ☐

(14) What % of your total energy requirement is provided by C.H.P.?

(15) What % of planned operating hours was the CHP system non operable?

(16) Currently, what do you see as key reasons for investing in C.H.P?

	very important	***quite important***	***not importan t***
- *Avoiding Environmental levies*	☐	☐	☐
- *Anticipating future regulations*	☐	☐	☐
- *Corporate social responsibility*	☐	☐	☐
- *Cost savings/Greater efficiency*	☐	☐	☐
- *Other (Please Specify)*	☐	☐	☐

(17) Who was responsible for the design and management of the project

In-house staff ☐

External Consultants ☐

(18) Was it carried out as a separate project or part of a larger project?

Separate ☐ *Larger* ☐

(19) By whom was the system installed?

CHP manufacturer/supplier ☐

Specialist contractor ☐

(20) What level of satisfaction do you have with the CHP system?

High ☐

Medium ☐

Low ☐

(21) Do you envisage installing another CHP system in the next 3 years?

Yes ☐ *No* ☐

(22) If NO, why not?

(23) If YES, what would be the key drivers?

Legislation/compliance issues e g levies ☐

Environmental/Energy saving benefits ☐

Economic Benefits ☐

Financial Assistance ☐

Plant Replacement ☐

(24) How was the CHP scheme financed?

Third party i.e. lease (>50% of costs) ☐

Own resources (>50% of costs) ☐

Grant (>50% of costs) ☐

(25) How significant was the availability of financial assistance?

Very significant ☐

Significant ☐

Indifferent ☐

(26) How was the scheme financially evaluated?

Pay back .... Yrs

IRR .... %

NPV .... £

Other ....

(27) What were the key difficulties associated with adopting C.H.P.?

Lack of adequate financial resources/assistance ☐

Complex technology/ non core business ☐

Lack of easy decision making information/tools ☐

Lack of co-operation of local electricity supplier ☐

Lack of commitment from more senior personnel ☐

Appendix 5.4

Principles underlying the Statistical Analysis

The earlier desktop analyses-case study examination and review of data for existing CHP installations in SMEs- were empirical in the determination of the likely key drivers for CHP installations. These were then used to develop the discussion points for the qualitative interviews and thereafter the survey questionnaire. The results are analysed by the use of a variety of techniques in particular statistical analysis with SPSS and conversational analysis using NUD*IST.

Statistical Package for Social Scientists (SPSS)

Key relationships were tested to determine any mathematical linkages in the quantitative analysis. Tests carried out with SPSS include: Frequencies, means, medians, Chi-Squares, histograms (with normal curves), bar charts, comparing means, cross-tabulations, scatter diagrams, regressions, analysis of variances. These were carried out within a variety of scenarios such as hypotheses testing with one tailed and two tailed tests. The parametric tests were carried out as independent samples (between industry sectors) or as paired samples within industry sectors but across size spectrums. Response data collected for each question are coded into variable groups for ease of carrying out frequency analyses. Two types of variables were used in the data analysis- String, numeric (ordinal, nominal, interval). Frequency analysis is often reported in the form of graphs and charts such as bar charts, histograms and pie charts. Pie charts indicate differences in frequencies or percentages among categories of nominal variables by displaying the categories as segments of a circle.

Appendix 5.4

Bar charts are constructed by labelling the categories of the variables along the horizontal axis and by drawing rectangles of equal width for each category. The height of each category is proportional to the frequency or percentage of a category. Histograms are used to make a comparison between different types of data collected for a single variable. In this case the rectangles are constructed continuously to show that the variable is continuous and intervals rather than discrete categories are displayed across the horizontal axis. The heights of the rectangles in the Histogram reflect the percentage or frequency of the interval. Histograms are used to determine the mean, median and mode of a data set. The mean this is frequently considered to be the arithmetic average and is a measure of the central tendency of the data. The median is a positional measure that divides the distribution into two equal parts. The mode is the category or observation that occurs most frequently in the distribution. Parametric tests are used to compare the means between independent or unrelated samples or between related or paired samples. They are used on interval data, which are represented in normal curve within a histogram. The test for this is referred to as the t test. Non-parametric tests do not make any assumption about the data population and are sometimes therefore referred to as distribution or assumption free. They generally occur in the form of cross tabulations for chi square tests and the Mann Whitney test, indicating the goodness of fit of a particular hypothesis with the data collected. In non-parametric testing the nominal and ordinal variables are in categories rather in a continuous distribution. One tailed tests and two tailed tests refer to the level of accuracy or significance that the data calculation was carried out.

Linear regression techniques were also used to determine the relationship (if any) between independent data sets. They were useful as a predictive tool for developing mathematical relationships in the Decision Support Model.

Coding of transcripts from interview data using NUD*IST (N4)

(N4) is a tool kit to assist and support individuals and groups who are engaged in qualitative research processes. As a tool kit, it does not displace the researcher or processes as the central area of activity. But rather, N4 supports the processes or activities in the business of doing qualitative research.

Using N4 in a project means that the researcher can engage with and get to know the data, and build out of the analysis the story or stories to be told about the project.

N4 does provide tools to do things that you couldn't do or do so well without the software. The researcher is able to ask questions and seek answers to those questions that without N4, they could not or dared not ask. While N4 provides the tools to execute this "question – answer", these tasks are researcher directed and implemented.

The following points are some of the tasks or processes researchers have named as important to them and what they do. They are the starting points at which researchers have come to N4 training courses and from there develop, as their skills evolve.

Appendix 5.4

The software is useful for the following aspects:

- Seeing the story in complicated data finding out what's going on;
- Sorting data into theme areas so that all the "stuff" about a theme is in one piece and it can be viewed all together;
- Locating key words or phrases, sorting them and storing them in one place so that they can be reviewed;
- Linking ideas together;
- Comparing groups or sites or stages to see how they are different;
- Locating all answers for a question and then looking for key ideas expressed in the responses;
- Making categories for thinking about the data and to see more general shapes in the data;
- Using categories to code data and then examining each category to see what it is referring to;
- Doing the data justice – not just summarising it but really exploring;
- Re-coding or resorting data which no longer "fits" where it was previously categorised;
- Looking to see if there are linkages between categories or theme areas;
- Testing or checking to see if a link or a pattern between categories is really there;
- Managing or knowing where all the data is, so it doesn't become lost or misplaced.

Use of WQSR NUD*IST v4 (N4) in this research process

QSR NUD*IST v4 was used as the research tool for assessing the key drivers from the qualitative assessments. The software was used to analyse the statements of the interviewees in a way that identified particular themes and thereby afforded cross-tabulation techniques for common factors to be identified between the interviewees as key policy drivers for CHP schemes. The NUD*IST software was used as a research tool to explore and identify themes from the qualitative data collected during the semi-structured interviews. It was used to link the ideas, keywords and philosophies of the interviewees in a way that allow for the emergence of macro policy initiatives. The analysis was carried out by firstly importing the transcribed recording of the interviews into a NUD*IST document system by converting a document file into a text-only file format. The different text files were then stored in an index system. The various text data files were then broken down into discrete categories are representing different phenomena for testing and analysis. These categories are represented as nodes in the index-coding tree (Figure 6.1) and labelled as such. In addition a number of free nodes were also adopted for tests that would be carried out across the initially identified categories. The format of the analysis of the data took the form of browsing the established for any common phenomenon from the interviewees and developing new nodes and "child" nodes for a deeper examination of the amalgamated responses of the interviewees. The types of examination, the phenomena that were categorised as nodes and the reformatted data are shown in Figure 6.1 as a display of index nodes used for coding transcripts of interviews.

APPENDICES 6.1- 6.2

Appendix 6.1

Transformation Codes for Analysing Data in SPSS

Quantitative Survey

Section 1 –Information on the Organisation

(1) Jtitle (Nominal string variable)

(2) auth _2

Director 1 □ Senior Manager 2 □
Head of Department 3 □ Junior Manager 4 □

(3) resp_3

Operations 1 □ Engineering 2 □ Environment 3 □

Finance 4 □ Development 5 □ Other_ 6__

(4) Owner 4

Private Limited 1 □ : Quoted Public 2 □ : Government/Local Authority 3 □

(5) Sector 5

Engineering 1 □ Property Management/Domestic 2 □

Food, Drink& Tobacco 3 □ Textiles Leather & Clothing 4 □

Paper printing & Publishing 5 □ Public Service(State)_____6__ □

Construction 7 □ Manufacturing 8 □ Chemicals 9 □ Utilities 10 □ Hotel 10 □

Transport 12 □ Iron & Steel 13 □ Agriculture 14 □

(6) t Over 6

Less than £2 million 1
£2 million or over but less than £5 million 2
Greater than £5 million 3

(7) Locate 7

Individual building on own site 1 □ Industrial Estate 2 □

(8) ownbldg 8

Own 1 □ Lease □
Remaining period: ≤ 10 years 2 □ : >20 years 3 □ : > 50 years 4 □

(9) envmgt 9

No 0 ☐ Yes 1 ☐ Don't Know 9 No response 8

SECTION 2-The decision process for the installation of a CHP plant

(10) Which of these sources of information on CHP has been or would be most useful to you.

	Very 1	Not Very 2	No Use 3
Gbp_10.	☐	☐	☐
Sat_10	☐	☐	☐
Conf_10	☐	☐	☐
Cons_10	☐	☐	☐
Ind_10	☐	☐	☐

(11) What were the key drivers for installing C.H.P. (rank in order 1=best, 5=worst, if you can)?

Ecben_11	☐
Finas_11	☐
Excon_11	☐
Plrpl_11	☐
Other	99

(12) **decis-12**

Energy/Environmental Manager	*1*	☐
Line Manager	*2*	☐
Finance Manager/Director)	*3*	☐
Director/Board/Committee	*4*	☐
Other	99	

***(13)* aware_13**

Please tick:	*Very 1*	☐	*Not 2*	☐

(14) ener_14 (Ordinal numeric Variable)

(15) hours _15 (Ordinal numeric variable)

(16) regs_16.

	Very (1) important	***Quite (2) important***	***Not (3) importan t***
- *Envlv_16*	☐	☐	☐
- *Fregs_16*	☐	☐	☐
- *Cresp_16*	☐	☐	☐
- *Costs_16*	☐	☐	☐
- *Other_16*	☐	☐	☐

(17) design _17

In-house staff ☐

External Consultants
2
Other
99

(18) sepr_18

Separate 1 *Larger 2*

(19) insta_19

CHP manufacturer/supplier 1

Specialist contractor 2

Other 99

(20) sati_20

High 1

Medium 2

Low 3

(21) inst_21

Yes 1 *No 0*

(22) Ynot_22 (Nominal string variable)
-8 No Response -9 Don't Know

(23) **yesy_23**

1 Legislation/compliance issues e g levies

2 Environmental/Energy saving benefits
3 Economic Benefits

4 Financial Assistance

5 Plant Replacement

(24) **fnce_24**

Third party ie lease (>50% of costs) 1 ☐

Own resources (>50% of costs) 2 ☐

Grant (>50% of costs) 3 ☐

(25) signf_25

Very significant 1 ☐

Significant 2 ☐

Indifferent 3 ☐

(26) How was the scheme financially evaluated?
Pybk_26 (Ordinal Interval variable)…. Yrs

Irr_26 …………………….. %

Npv_26…………………… £

Other_26 (ordinal variable)…………..

(27) diff_27

Lack of adequate financial resources/assistance ☐

Complex technology/ non core business
2 ☐

Lack of easy decision making information/tools
3 ☐

Lack of co-operation of local electricity supplier
4 ☐

Lack of commitment from more senior personnel 5 ☐

Other Variables Used in the Analyses, by Re-Coding "Similar Responses"

Question 2
authrc_2

Question 10
gbprc_10, satrc_10, conrc_10, cosrc_10, indrc_10

Question 16
envrc_16, frerc_16, crerc_16, cosrc_16, satrc_16, conrc_16

Question 20
Satrc_20

Question 24
Fncrc_24

Question 25
Sigrc_25

useful sources of information-Govt Best Practice (rev) * useful sources of information-Self Ass Tool (rev) Crosstabulation

			Useful sources Of	
			Not very useful	Total
Useful sources of Information-Govt Best Practice (rev)	Very useful	Count	**9**	**83**
		% within useful sources of information-Govt Best Practice (rev)	**10.8%**	**100.0%**
		% within useful sources of information-Self Ass Tool (rev)	**75.0%**	**91.2%**
	No Use	Count	**3**	**8**
		% within useful sources of information-Govt Best Practice (rev)	**37.5%**	**100.0%**
		% within useful sources of information Tool (rev)	**25.0%**	**8.8%**
Total		Count	**12**	**91**
		% within useful sources of information-Govt Best Practice (rev)	**13.2%**	**100.0%**
		% within useful sources of information Tool (rev)	**100.0%**	**100.0%**

			Useful sources of information-Self Ass Tool	
			no response	very useful
Useful sources of Information-Govt Best Practice (rev)	very useful	Count	**9**	**65**
		% within useful sources of information-Govt Best Practice (rev)	**10.8%**	**78.3%**
		% within useful sources of information-Self Ass Tool (rev)	**90.0%**	**94.2%**
	No Use	Count	**3**	**4**
		% within useful sources of information-Govt Best Practice (rev)	**12.5%**	**50.0%**
		% within useful sources of information Tool (rev)	**10.0%**	**5.8%**
Total		Count	**10**	**69**
		% within useful sources of information-Govt Best Practice (rev)	**11.0%**	**75.8%**
		% within useful sources of information Tool (rev)	**100.0%**	**100.0%**

Appendix 6.2

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	4.722[a]	2	.094
Likelihood Ratio	3.634	2	.163
Linear-by-Linear Association	.012	1	.913
N of Valid Cases	91		

a. 2 cells (33.3%) have expected count less than 5. The minimum expected count is .88.

APPENDIX 8.1

Energy Conversion Factors (SI Units) used in developing the Internal Decision Support System

The S I (Systeme Internationale) unit of energy is the Joule. Large quantities are expressed as multiples indicated by the following prefixes:

Factor	Prefix	Symbol
10^3	kilo	k
10^6	mega	M
10^9	giga	G
10^{12}	tera	T
10^{15}	peta	P
10^{18}	exa	E

Conversion factors for Energy Units

to / from	**Btu**	**Joule**	**kWh**	**therm**
Btu	1	1.055×10^3	0.2931×10^{-3}	10×10^{-6}
joule	0.948×10^{-3}	1	0.2778×10^{-6}	9.48×10^{-9}
kWh	3.412×10^3	3.6×10^6	1	32.12×10^{-3}
therm	100×10^3	105.5×10^6	29.31	1

Energy Value of Fuels

Fuel	**Heat Supplied Basis***
Fuel Oil	185 MJ/gallon
Fuel Oil	40.8 MJ/litre
Fuel Oil	43.3 MJ/kg
Fuel Oil	43.3 GJ/tonne
Electricity	3.6 MJ/kWh
Natural Gas	38.6 MJ/m3
Derv	177 MJ/gallon
Other Liquid Fuels	189 MJ/gallon
Tonne Coal equivalent**	26.5 GJ/tonne

Other conversion factors:
1 ton =1.016 tonne
1lb =0.4536kg
1 gallon =4.546 litres

*The heat supplied basis energy value is the energy a fuel is capable of providing at the point of use. The primary fuel equivalent takes into account losses incurred in refining fuels, or converting them into familiar forms, and losses in distribution.

** The tonne coal equivalent is a unit defined for statistical purposes in the UK as 250 therms, which is different from international convention.

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